HUG

Digital Subperiosteal implants

A new way to treat complex cases
and severe bone atrophy

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Foreword

Implantology is a field built on the constant pursuit of solutions for patients who, for too long, were told that nothing could be done. Severe bone atrophy, complex anatomical conditions, repeated failures — these are the cases that define us as clinicians and push us to innovate.

This book was born from a simple but powerful observation: subperiosteal implants are experiencing a renaissance. Thanks to digital technologies — CAD/CAM design, 3D titanium printing, and finite element analysis — what was once an unpredictable procedure has become a precision-driven science.

The HUG® implant system represents the culmination of years of clinical practice, fundamental research, and collaborative development involving academic institutions and industrial partners, including Biotech Dental. But beyond the hardware, what truly defines HUG® is its concept: a comprehensive nine-pillar framework designed to control every biological and surgical variable that determines long-term success.

This book is intended for dental surgeons who wish to understand not just how to place a subperiosteal implant, but why each decision matters — from material selection to surface treatment, from biomechanical validation to soft tissue management. Our goal is simple: fewer complications, better tissue integration, and long-term clinical reliability for every patient who has been told there is no other option.

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Introduction

The Return of Subperiosteal Implants

For decades, subperiosteal implants occupied a stigmatised position in implantology. Their historical failure rates led the profession to abandon them. Digital manufacturing has changed everything — but technology alone is not enough. A complete conceptual framework is required. This is the HUG® Concept.

For decades, subperiosteal implants occupied a marginal position in the implantology landscape. Their historical failure rates, largely attributable to the limitations of cast Vitalium technology and the absence of any guiding biological concept, led the profession to abandon them in favour of endosseous implants. Patients with severe bone atrophy were left with difficult choices: extensive bone grafting, zygomatic implants, or complete dentures.

The convergence of cone-beam CT imaging, computer-aided design, additive titanium manufacturing, and surface science has created a fundamentally new category of subperiosteal implant — one that has more in common with precision orthopaedic surgery than with its historical predecessor.

A Historical Parallel

In 1938, Stock placed a Vitalium implant directly into an extraction socket. The patient reportedly went 17 years without major complications. Most historical series of cast Vitalium subperiosteal implants report long-term success in only about one case out of two — unacceptable by contemporary standards.

By contrast, in 1982 at the Toronto Conference, Brånemark presented his titanium endosseous implant after 15 years of meticulous research. What distinguished Brånemark's implant from Stock's was not merely the choice of metal, but an entirely new framework: a defined protocol, precision engineering, a prosthetic philosophy, and above all — a biological concept. The concept was osseointegration, and it changed everything.

Subperiosteal Implants: Historical vs Modern		
Characteristic	**Historical (Vitalium, 1945)**	**HUG® Implant (Grade 23 ELI Titanium)**
Material	Vitalium (Co-Cr alloy)	**Ti-6Al-4V Grade 23 ELI**
Manufacturing	Casting from impression	**CAD/CAM + 3D metal printing**
Surface treatment	Smooth, untreated	**Gyroid lattice + anodization**
Validation	None	**Finite element analysis per patient**
Surgical protocol	Empirical	**9-Pillar conceptual framework**
Long-term success	~50% (1 in 2 cases)	**Protocol-driven predictability**
Biological concept	None	**Osseointegration + tissue management**

Figure 1 — Comparative overview of historical Vitalium subperiosteal implants versus the modern HUG® Grade 23 ELI titanium system, illustrating the paradigm shift in material, manufacturing, surface treatment, validation, and conceptual framework.

The Same Revolution, Again ?

Today, we are at an inflection point. On one side, a cast Vitalium subperiosteal implant shaped approximately to the bone surface, with no surface treatment, no biological guidance, and no digital validation. On the other, a 3D-printed Grade 23 ELI titanium implant, precisely adapted to patient anatomy, with an optimised gyroid lattice structure, anodised surface, finite element validation, and a nine-pillar management protocol.

The question is not whether these two implants look different. The question is whether we can achieve the same conceptual leap — the same transformation in clinical predictability — that occurred between the Stock implant and the Brånemark implant. The answer, grounded in science rather than optimism, is yes.

References

Cohen DJ, Cheng A, Kahn A, et al. Novel Osteogenic Ti-6Al-4V Device For Restoration Of Dental Function In Patients With Large Bone Deficiencies. Sci Rep. 2016;6:20493.

Adell R, Hansson BO, Brånemark PI, Breine U. Intra-osseous anchorage of dental prostheses. Scand J Plast Reconstr Surg. 1970;4(1):19–34.

Goudal M, Bailly C. Treating posterior mandibular atrophy using CAD/CAM subperiosteal implants. Implant Practice US. 2023.

Chapter 1 — Material & Osseointegration

The Titanium Grade 23 ELI Advantage

Before addressing the nine pillars, a fundamental question must be answered: can a modern CAD/CAM subperiosteal implant actually achieve osseointegration? The answer determines whether these implants represent a temporary rehabilitation solution or a true long-term treatment modality.

1.1 Titanium Grade 23 ELI

The HUG® implant is printed in Titanium Grade 23 ELI (Ti-6Al-4V Extra Low Interstitials). This material is closely related to Grade 5 titanium — the workhorse of implant dentistry — but with meaningful differences in mechanical and biological properties: improved ductility, high fatigue resistance, and superior biocompatibility. These properties are not merely marketing attributes; they are prerequisites for an implant that must resist significant bending and torsional forces over a clinical lifetime.

1.2 Evidence for Osseointegration

Animal Studies

A pivotal 2016 study by Cohen and colleagues published in Scientific Reports provided some of the earliest histological evidence of osseointegration in 3D-printed titanium subperiosteal implants [1]. At six weeks, histological sections showed new bone formation in contact with the fixation screws, on the inner surface of the implant, and partially covering its external surface. This represents partial — not yet complete — osseointegration.

Clinical Note Some parts of the implant remain partially extraosseous under the periosteum at six weeks. Achieving more complete coverage requires additional biological management — which Pillars 5 and 6 of the HUG® Concept address directly.

First Human Case Report

The same 2016 paper described the first human case: a 3D-printed Ti-6Al-4V implant placed in a patient with large mandibular bone deficiency, fixed with four mini-screws, loaded at three months. At eight months, CBCT confirmed full osseointegration. The implant was stable and functional.

The question is no longer whether 3D-printed titanium subperiosteal implants can integrate. The question is how to make integration consistent, predictable, and reliable across all patient populations — and that is the purpose of the nine pillars.

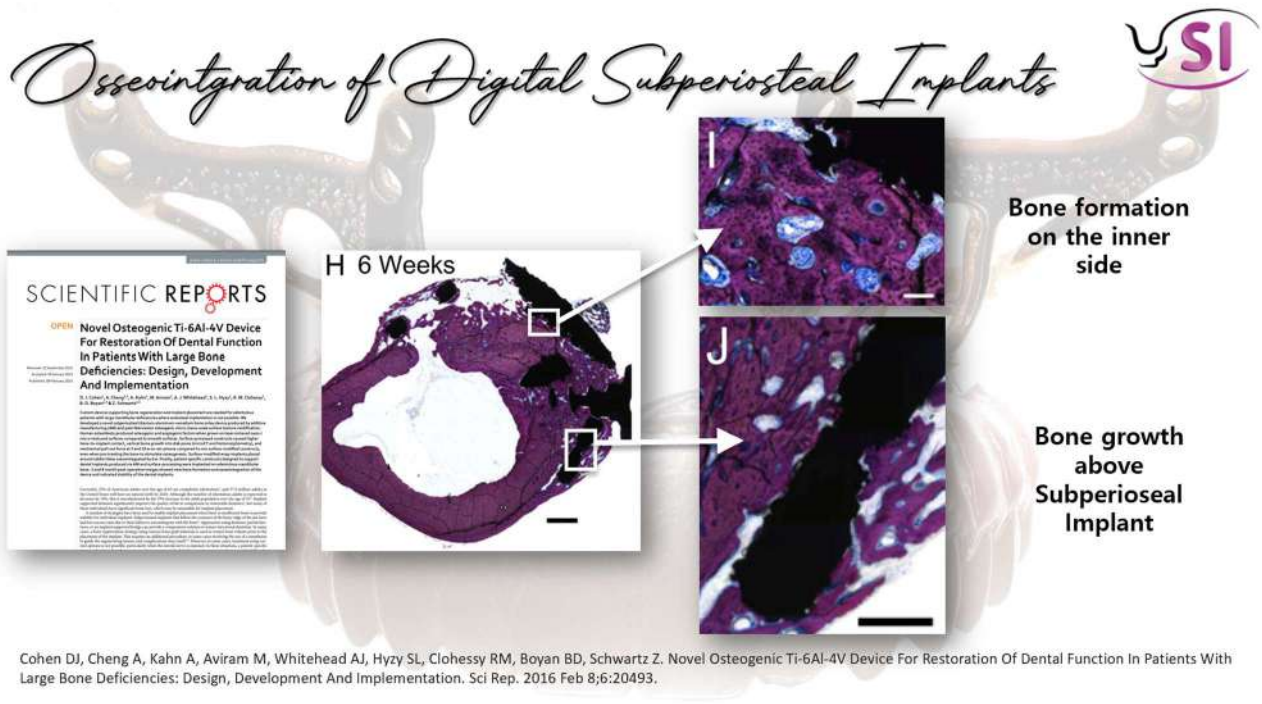


Figure 1.1 — Histological section of a porous titanium subperiosteal implant placed around the femur of a rabbit after 6 weeks of healing. New bone formation is observed both on the inner surface of the implant, in contact with the cortical bone, and on its outer surface, demonstrating the osteoconductive properties and biological integration of the implant. Adapted from Cohen et al., 2016.

1.3 Biological Behaviour of the Titanium Plate

When a titanium plate is placed under the periosteum in contact with bone, three questions arise: Does it adapt with sufficient precision to allow biological contact? Will new bone grow to cover it? Under what biological conditions does this occur? The answers depend on a combination of the precision of fit, surface properties, periosteal biology, and the presence of biomaterials to guide tissue response.

This is why Pillars 1 (gyroid lattice), 2 (anodization), and 6 (tissue management with biomaterials) are so tightly linked. Each addresses a different aspect of the same biological challenge: promoting bone formation in contact with and covering the titanium body.

References

Cohen DJ, Cheng A, Kahn A, et al. Novel Osteogenic Ti-6Al-4V Device For Restoration Of Dental Function In Patients With Large Bone Deficiencies: Design, Development And Implementation. Sci Rep. 2016;6:20493.

Beltrán V, Weber B, Lillo R, et al. Histomorphometric Analysis of Osseointegrated Grade V Titanium Mini Transitional Implants in Edentulous Mandible by BS-SEM. Metals. 2021;11:2.

Hyzy SL, Cheng A, Cohen DJ, et al. Novel hydrophilic nanostructured microtexture on direct metal laser sintered Ti-6Al-4V surfaces enhances osteoblast response in vitro. J Biomed Mater Res A. 2016;104(8):2086–98.

Chapter 2 — Scientific Literature Review

Modern Subperiosteal Implants: What the Evidence Really Tells Us

Modern subperiosteal implants demonstrate reliable short-term survival rates, but long-term evidence remains limited to a decade. The key determinant of clinical success is not the implant itself, but the precision of its design, the rigour of its surgical placement, and the biomechanical adequacy of the prosthetic rehabilitation.

2.1 Introduction and Methodological Framework

This chapter presents a systematic review of the contemporary scientific literature on patient-specific, additively manufactured subperiosteal implants (CAD/CAM subperiosteal implants — CSI). The objective is to provide an evidence-based appraisal of clinical indications, surgical and prosthetic protocols, reported outcomes, and documented limitations, while contextualising these data within the HUG® Concept developed at the Subperiosteal Institute.

A structured bibliographic search was conducted across PubMed and Google Scholar using the terms *"Subperiosteal implant OR customized subperiosteal implant OR subperiosteal personalized implants"*. The search period extended from 05/01/2018 to 31/12/2024. Of the **482 articles** initially identified, **12 studies** met the eligibility criteria after independent screening by two reviewers. These 12 publications, encompassing **276 patients** and **357 implants**, form the evidence base of the present chapter.

It must be emphasised from the outset that this body of literature remains heterogeneous in terms of study design, follow-up duration, surgical technique, and outcome reporting. This variability is a fundamental limitation when drawing population-level conclusions.

2.2 Epidemiological Profile of Treated Patients

Across the selected studies, the mean patient age was **62 years** — a figure that merits reflection. Our clinical position holds that subperiosteal implants are ideally suited to elderly patients (> 60 years), in whom conventional implant-supported solutions may be biomechanically or surgically contraindicated. However, the literature demonstrates that this treatment is being offered to a broader patient population. There was a slight female predominance (55% women vs. 45% men), and the mean follow-up across studies was **19.4 months**.

Regarding implant location, **66%** of cases involved the maxilla and **14%** the mandible (20% unspecified). This distribution reflects the primary clinical indication: *the severely atrophic maxilla* represents the dominant indication for subperiosteal rehabilitation, followed by unilateral mandibular cases. The fully edentulous mandible can frequently be rehabilitated using a conventional All-on-4 approach, owing to the relative preservation of bone in the anterior symphyseal region.

2.3 Indications and contra-indications of Digital Subperiosteal Implants

Patients considered for digital subperiosteal implants are typically elderly individuals, often over 60 years of age, presenting with severe maxillary or mandibular atrophy that prevents the placement of conventional implants without extensive grafting procedures. Common indications include severe premaxillary bone deficiency, contraindications to sinus grafting, posterior mandibular atrophy with less than 7 mm of bone above the inferior alveolar nerve, severely resorbed symphyses, and rehabilitation following multiple implant failures. Healed edentulous ridges represent the most favorable clinical situation, allowing optimal implant adaptation and soft tissue management.

Contraindications are generally similar to those of conventional implant therapy and include uncontrolled systemic diseases, poor oral hygiene, active periodontal disease, ongoing bisphosphonate-related complications, and a history of head and neck radiotherapy when healing potential is compromised. Caution should also be exercised in patients with severe bruxism and heavy smoking habits, both of which are associated with increased mechanical and biological complications and may negatively affect long-term outcomes. Based on our clinical experience, we consider active smoking to be an absolute contraindication for this procedure because of the substantially increased risk of soft tissue recession, which can jeopardize implant coverage and long-term treatment success.

2.4 Surgical Design: Type of Rehabilitation and Implant Configuration

Full-arch rehabilitation accounted for **61%** of reported cases, with partial edentulism in **14%** (25% unspecified). Two principal surgical configurations were described across the literature:

- **Bilateral dual-implant design** (two separate implants connected by a prosthetic framework): 71% of cases
- **Monobloc (one-piece) implant**: 29% of cases

Current consensus, supported by finite element analysis data from Ayhan and Cankaya, favours the **bilateral dual-implant design** for full-arch rehabilitation. Monobloc implants, while historically employed, present significant manufacturing complexity without offering measurable biomechanical advantages in terms of load distribution to the underlying bone. The HUG® system adopts a bilateral architecture as its foundational design principle.

2.5 Anaesthesia and Operative Time

Anaesthesia data were available for 76% of patients. Local anaesthesia was employed in **56%** of cases; general anaesthesia or conscious sedation in **20%**. The mean operative time, reported in 53% of studies, was **93 minutes** overall — ranging from approximately 44 minutes for mandibular partial cases to 146 minutes for complete edentulous rehabilitations.

In the context of the HUG® protocol, mandibular partial procedures require approximately 90 minutes, owing to the systematic use of a bone-cutting guide (osteotomy guide) and the application of

biomaterial coverage — procedural elements that contribute to increased operative time but are considered essential to predictable outcomes.

2.6 Prosthetic Protocols: Provisional and Definitive Restorations

2.6.1 Provisional Prostheses

Provisional restorations were used in **76%** of patients. Among these:

- 31.5% were screw-retained
- 29% were cemented
- 2.5% were removable
- 37% were not documented or represented mixed solutions

Immediate prosthetic loading was performed in **24%** of cases; **39%** received their provisional prosthesis within 48 hours to 15 days postoperatively. The provisional material was systematically resin-based across all studies, with only one study specifying the use of a rigid internal framework (15 patients).

This absence of systematic framework reinforcement is a critical limitation of the published literature. In full-arch cases treated with bilateral subperiosteal implants, the provisional restoration must integrate a rigid metal framework interconnecting both implants. Failure to do so introduces micromovement during the osseointegration phase, with potentially deleterious consequences for implant stability. The HUG® protocol mandates:

- Full-PMMA bridge for unilateral cases
- Titanium framework with acrylic teeth for full-arch cases — considered equivalent to a definitive prosthetic solution

2.6.2 Definitive Prostheses

Permanent prostheses were delivered between **2 and 6 months** postoperatively in the majority of studies. Two-thirds of final restorations were fixed (37% screw-retained, 29% cemented); 6% were removable with attachment systems or telescopic pillars. Materials included layered zirconia, metal-ceramic, and machined titanium frameworks with acrylic teeth.

2.7 Clinical Outcomes and Survival Rates

Despite the heterogeneity of protocols, the aggregated clinical data demonstrate consistently high implant and prosthetic survival rates. Across the 12 selected studies:

- **Prosthetic survival rate: 99.6%**
- **Implant survival rate: 95.8%**

The three most frequently reported complications were: (1) exposure of an implant arm, (2) infection, and (3) failure of implant adaptation to the bone surface. Importantly, arm exposure — which occurred in approximately **13%** of cases — did not systematically compromise implant survival when managed conservatively.

First Author (Year)	n Patients / Implants	Follow-up	Survival Rate	Main Finding
Vaira et al. (2024) Maxilla — full arch	36 / 72	5 years	100%	9.7% Class I arm exposure; success rate 90.3%
Van den Borre et al. (2024) Maxilla	40 / n.r.	3 years	100%	Gingival recession in 65% of patients; risk factor: thin biotype
Van den Borre et al. (2025) Mandible	19 / n.r.	~2 years (804 days)	92.5%	Recession on 32.25% of implants
Vaira et al. (2024) Mandible — partial	17 / 30	22 months	100%	0% gingival recession — protocol-dependent result
Anitua et al. (2024) Systematic Review	227 / 227	21.4 months	97.8%	25.6% partial arm exposure; infection in 5.3%
Loginoff et al. (2025) Maxilla	n.r. / 10	10 years	80%	Oldest long-term data; limited to 10 implants
Onica et al. (2024) Maxilla & mandible	36 / 61	6 years	54.1%	Highest reported failure rate (45.9% at 6 years); maxillary cases significantly worse (p = 0.002); late, unreinforced prostheses
Zielinski et al. (2025) Maxilla — comparative	150 / n.r.	5 years	97.1% (CSI) vs 96.3% (zygo)	CSI: fewer complications (5.6% vs 12.4%); superior soft-tissue stability

Table 2.1 — Comparative summary of selected clinical studies on additively manufactured subperiosteal implants (2024–2025). CSI: custom subperiosteal implants; zygo: zygomatic implants; n.r.: not reported.

2.8 Long-Term Evidence: A Critical Appraisal

2.8.1 Vaira et al. (2024) — 5 Years, Atrophic Maxilla

The study by Vaira and coworkers is to date one of the most methodologically robust long-term reports in the field. Thirty-six patients received 72 bilateral subperiosteal implants for full-arch maxillary rehabilitation. At five years, the implant survival rate reached **100%**, with an overall success rate of **90.3%**. The primary complication observed was Class I arm exposure (9.7% of implants), managed conservatively with topical chlorhexidine and intensified oral hygiene maintenance. Notably, no cases progressed to infection or implant failure.

2.8.2 Loginoff et al. (2025) — 10 Years: The Longest Available Follow-Up

The study by Loginoff and colleagues represents the most extended follow-up currently published in the subperiosteal implant literature, spanning **10 years** of clinical observation in maxillary cases. A survival rate of **80%** was reported at this timepoint. Failures were attributed to poor implant-bone adaptation and persistent peri-implant inflammation.

This result, while superior to historical implant data from earlier generations, must be interpreted with significant caution: the study is limited to **10 implants**, of which 2 were removed. The scientific level of evidence is therefore weak. Furthermore, the protocol employed in this series — bone preparation without a surgical guide, no attention to attached gingiva width, and delayed cemented prosthetic loading at 5 months — diverges markedly from current best practice and from the HUG® protocol.

Prosthetic pillars were integrated into the framework and protruded conspicuously through the gingival tissue, a configuration that may generate micromovements during the osseointegration phase. Given these methodological limitations, substantially **better long-term outcomes** can be expected with optimised contemporary protocols.

2.8.3 Onica et al. (2024) — 6 Years: An Outlier That Demands Explanation

The six-year report by Onica and colleagues is, on first reading, the most concerning long-term study in the entire subperiosteal literature. In a cohort of 36 patients rehabilitated with 61 additively manufactured titanium implants, the implant survival rate fell to **54.1% at six years**, with only 9 of the 36 patients entirely free of complications. This is starkly inconsistent with the 90–100% survival reported by most contemporary series, and it cannot simply be dismissed. It deserves the opposite — close and honest scrutiny — because a result this divergent is almost never explained by the implant itself, but by the protocol that surrounds it.

Several features of this work command respect. It is one of the few genuine long-term cohorts in the field — far more substantial than the ten-implant series that previously represented the longest follow-up. The authors report their failures transparently, document the chronology of complications in detail, and resist any temptation to flatter their own technique. This honesty is precisely what the discipline needs: a poor result, openly reported, teaches more than an unblemished one. The cases were, moreover, operated in 2017–2018, at the very beginning of the digital subperiosteal learning curve, and in a predominantly maxillary population — the single most demanding indication in the field.

The data themselves indicate where the problem lay, because the collapse in survival was not uniform — it was concentrated in the maxilla. At six years, only **18.2%** of maxillary cases remained complication-free, against **72.7%** of mandibular cases — a difference that reached statistical significance (**$p = 0.002$**). As almost four of every five implants in this series were maxillary, the headline survival figure is, in effect, a maxillary figure; the mandibular results are broadly consistent with the remainder of the literature.

The decisive factor, however, is prosthetic. In this protocol the impression for the provisional bridge is taken only 2 to 7 days after surgery. The definitive fixed restoration was delivered only **6 to 12 months after surgery**, the patient wearing an acrylic screw-retained provisional in the interim, with no rigid metal framework interconnecting the two implants during the critical osseointegration window. Prolonged function on an under-reinforced resin provisional invites precisely the micromovement that this chapter repeatedly identifies as the enemy of bony integration. The complications then followed a predictable sequence: early frame exposure, progressive exposure and mobility, and — in the cases taken to salvage surgery — an acceleration rather than a resolution of the problem.

The soft-tissue picture tells the same story. Progressive buccal exposure of 2 to 4 mm appeared from roughly 24 months, preferentially at sites where hygiene was difficult to maintain. A slow-resorbing membrane was used, yet soft-tissue management appears to have been insufficient for the demands of these cases, and the prosthetic emergence was, in several instances, positioned too far to the vestibular — drawing the gingival margin away from the very supports it was meant to protect. Excessively vestibularised pillars, inadequate keratinized-tissue augmentation, and late, unreinforced prostheses form a coherent and recognizable triad of failure.

None of these factors is mysterious, and — critically — none is intrinsic to the subperiosteal implant. Each is a modifiable variable of surgical and prosthetic technique: the position of the incision and the emergence profile, the systematic augmentation of keratinized tissue, and above all the immediate delivery of a rigid, framework-reinforced restoration in place of a delayed resin provisional. Read in this light, the Onica series is not an indictment of the technique but its most instructive cautionary tale: it quantifies, with uncommon honesty, the price of leaving these variables uncontrolled, and in doing so it reinforces the central thesis of this chapter — that long-term success is determined by the rigour of the protocol, not by the implant alone. The errors it documents are today clearly identifiable and, under a standardised contemporary protocol, could be largely avoidable. Nevertheless, this study should serve as a warning regarding the potential fragility of these subperiosteal implants, particularly highlighting the importance of maintaining adequate hygiene access beneath the definitive bridges.

2.9 Gingival Recession: The Central Clinical Challenge

2.9.1 Scope of the Problem

Across the literature, **gingival recession and soft-tissue complications** emerge as the dominant clinical challenge associated with modern subperiosteal implants. The Anitua et al. systematic review — the most comprehensive synthesis to date — reported **25.6%** partial arm exposure among 227 implants, with frank soft-tissue infection in only **5.3%** of patients. This critical distinction confirms that arm exposure does not systematically compromise implant osseointegration but remains an undesirable outcome that is clearly preferable to prevent.

2.9.2 Inter-Study Variability: The Decisive Role of Protocol

The magnitude of variability observed between studies in recession rates constitutes, in itself, a fundamental finding. The contrasting mandibular results from two studies with near-identical follow-up durations illustrate this point with particular clarity:

Study	Site	Follow-up	Patients / Implants	Gingival Recession
Van den Borre et al. (2025)	Mandible	24 months	19 / 40	32.25% of implants
Vaira et al. (2024)	Mandible (partial)	22 months	17 / 30	0%

Table 2.2 — Mandibular gingival recession rates in two comparable-duration studies, illustrating the protocol-dependence of soft-tissue outcomes.

The maxillary data are equally instructive: Van den Borre et al. reported a **100%** implant survival rate at 3 years yet documented gingival recession in **65%** of patients — a rate that, while not associated with infection, must be considered clinically unacceptable as a systematic finding. The primary identified risk factor was thin mucosal biotype, although surgical positioning of implant pillars, incision design, and tissue augmentation strategy are likely equally determinant.

The unavoidable conclusion is that *recession rates are overwhelmingly protocol-dependent*, not only implant-dependent. The design of the prosthetic abutments, the choice of incision, the quality and width of attached gingiva, the timing of prosthetic loading, and the rigidity of the provisional restoration are all modifiable variables that directly determine soft-tissue stability. This is the clinical rationale underlying the HUG® Concept: not merely an implant, but a **complete, standardised treatment protocol** designed to minimise — and ideally eliminate — gingival recession.

2.10 Subperiosteal Implants vs. Zygomatic Implants

Featured Study — *Zielinski R, Okulski J, Piechaczek M, et al. Five-Year Comparative Study of Zygomatic and Subperiosteal Implants: Clinical Outcomes, Complications, and Treatment Strategies for Severe Maxillary Atrophy.* J Clin Med. 2025 Jan 21;14(3):661.

Among all studies included in this review, the comparative investigation by Zielinski and colleagues stands as a landmark contribution — the first large-scale, direct comparison between subperiosteal and zygomatic implants in the severely atrophic maxilla. Its methodological design, sample size (**150 patients**), and 5-year follow-up place it at the apex of the available evidence hierarchy.

2.10.1 Study Design

One hundred and fifty patients with severe maxillary atrophy were allocated to one of two groups:

- **Zygomatic implants (ZI)**: 75 patients, 5-year follow-up
- **Custom subperiosteal implants (CSI)**: 75 patients, 5-year follow-up

Both groups were assessed for implant survival, complication rates, immediate loading capability, operative duration, soft-tissue stability, and sinus involvement.

2.10.2 Main Results

Criterion	Zygomatic Implants	Subperiosteal Implants
Implant Survival Rate	96.3%	97.1%
Complication Rate	12.4% (sinus-related complications and orbital damage)	5.6% (soft-tissue complications only)
Immediate Loading	Enabled	Enabled
Operative Duration	Shorter	Longer (bone harvesting, Bichat fat pad suturing)
Soft-Tissue Stability	Lower	Higher
Maxillary Sinus Lesions	Higher	Lower
Anatomical Risk Profile	High (orbital, sinus, trigeminal)	Low (subperiosteal, extrasinusal)
Manufacturing	Standardised, mass-produced	Custom, CAD/CAM 3D-printed

Table 2.3 — Head-to-head comparison of zygomatic vs. subperiosteal custom implants (Zielinski et al., 2025). Adapted from J Clin Med. 2025;14(3):661.

2.10.3 Clinical Interpretation

The survival rates of the two techniques were effectively **equivalent** at five years — a finding of considerable importance. Zygomatic implants have long represented the reference technique for the severely atrophic maxilla, based on two decades of published data. The demonstration of non-inferior survival for subperiosteal implants at this follow-up threshold is therefore a major scientific validation of the technique.

However, survival equivalence is not therapeutic equivalence. The Zielinski study identifies several dimensions in which subperiosteal implants offer a **superior clinical profile**:

- **Complication rate**: 5.6% vs. 12.4% for zygomatic implants — a more than twofold reduction in adverse events. Zygomatic complications included sinus infections, sinusitis, orbital

damage, and infraorbital nerve involvement — all associated with the transcutaneous and transsinusal trajectory of zygomatic fixtures.

- **Soft-tissue stability**: the subperiosteal approach, by remaining entirely extrasinusal and positioned on the cortical bone surface, avoids the mucosal and sinus complications inherent to zygomatic implants.
- **Anatomical safety**: zygomatic implants traverse the maxillary sinus, the infratemporal fossa, and approach the orbit — a risk profile that has no equivalent in the subperiosteal approach.
- **Reversibility and access**: a subperiosteal implant that requires explantation can be removed without structural damage to the maxillary sinus or orbital structures.

Subperiosteal implants were, on the other hand, associated with longer operative time — attributable to the need for cortical bone preparation, Bichat fat pad suturing, and biomaterial coverage. This represents a manageable surgical investment relative to the reduction in serious complication risk.

The Zielinski study positions custom subperiosteal implants as a credible, and in several respects preferable, alternative to zygomatic implants for the management of severe maxillary atrophy. The authors themselves conclude that subperiosteal implants may become the primary surgical option for this indication as clinical experience and evidence accumulates.

2.10.4 Implications for the HUG® Concept

These findings reinforce the clinical positioning of the HUG® implant as a first-line treatment option for the severely atrophic edentulous maxilla — not merely a fallback solution when other techniques fail. The anatomical simplicity of the subperiosteal approach, its extrasinusal positioning, its compatibility with local anaesthesia in the majority of cases, and its demonstrated short-to-medium-term survival equivalent to zygomatic implants collectively support this positioning.

When considering that these subperiosteal implants avoid palatal overcontouring of the prosthesis through digital preoperative positioning of the abutments, and that these procedures are less operator-dependent than freehand zygomatic implant placement, these results appear highly promising. Subperiosteal implants may therefore represent a credible alternative for the treatment of severely resorbed maxillae.

Each of these two surgical techniques may serve as a rescue solution for the other. The question remains as to which approach should be proposed as the first-line treatment. Given the lower invasiveness of subperiosteal implants, we believe that they may be worth considering before zygomatic implants. This issue remains to be clarified in future studies.

2.11 Protocol-Level Lessons from Literature

A synthesis of the available evidence yields a series of critical protocol determinants whose respect is associated with superior clinical outcomes. These represent the lessons learned from published failures and the foundation upon which the HUG® Concept is constructed:

- **Incision design**: crestal incision positioned on attached gingiva — too vestibular an incision is the single most frequently identified technical error across failure analyses.
- **Avoid cemented prostheses**: cemented restorations obscure the implant-prosthesis interface and complicate maintenance. Screw-retained restorations are preferred.

- **Immediate or very early loading**: loading must occur within 24–48 hours of surgery; delays beyond this window (including the «15-day» loading, identified explicitly as an error in multiple studies) are associated with micromovement and inferior outcomes.
- **Rigid prosthetic framework**: the provisional restoration must include a rigid metal framework interconnecting both bilateral implants. Resin-only provisionals are inadequate for full-arch bilateral cases.
- **Bone-cutting guide**: guided osteotomy ensures implant-bone congruence. Free-hand bone preparation — as described in several earlier-generation studies — is a primary cause of adaptation failure.
- **Soft tissue augmentation**: systematic attention to keratinised gingiva width and mucosal biotype, with biomaterial reinforcement where indicated.
- **Informed consent for innovative procedure**: from a medico-legal standpoint, subperiosteal implants retain the classification of an innovative protocol. Specific, documented patient consent is mandatory.

2.12 Current Limitations and Future Research Priorities

The present review identifies several structural limitations in the available literature that must inform both clinical practice and research design:

- **Follow-up duration**: maximum published follow-up is 10 years, represented by a single study of only 10 implants. No adequately powered long-term study currently exists.
- **Study design**: the majority of published studies are retrospective cohorts or case series. No randomised controlled trial has been conducted on this technique.
- **Outcome standardisation**: reporting of complications, recession, and success criteria varies substantially between studies, limiting meta-analytic synthesis.
- **Protocol heterogeneity**: the diversity of surgical and prosthetic approaches — incision design, biomaterial use, loading protocol, framework specification — means that published results may not be generalisable across different clinical settings.

Future research priorities include: (1) prospective comparative studies with standardised protocols; (2) randomised controlled trials comparing subperiosteal vs. zygomatic implants with extended follow-up; (3) histological and biomechanical studies of the peri-implant interface; and (4) patient-reported outcome measures including quality of life, masticatory function, and phonetic performance.

2.13 Conclusions

Modern custom subperiosteal implants demonstrate reliable survival rates in the short-to-medium term, comparable to zygomatic implants, with a more favourable complication profile. Gingival recession remains the central clinical challenge — but the evidence confirms that it is primarily a protocol-dependent complication, not an implant-inherent limitation. The HUG® Concept, through its rigorous surgical and prosthetic standardisation, is designed precisely to address this challenge.

The 12 studies selected in this review collectively support the following clinical conclusions:

- Custom subperiosteal implants offer a **viable and reproducible** alternative to zygomatic implants for the severely atrophic maxilla, with equivalent survival and fewer serious complications.
- In the mandible, outcomes are more variable and more strongly dependent on surgical technique — particularly incision design, pillar positioning, and soft-tissue management.
- The technique should still be categorised as **innovative** from a regulatory and medico-legal standpoint, with a maximum evidence horizon of approximately 10 years.
- Long-term clinical and basic science research on CAD/CAM subperiosteal implants is urgently needed.
- The HUG® system addresses the principal limitations identified in literature through its complete, protocolised treatment concept — surgical precision, biomaterial integration, and rigid immediate loading.

References

Birot L, Diss A. Évolution et perspectives des implants sous-périostés : une revue de la littérature. Focus Clinic. Le fil dentaire. 2024.

Ayhan M, Cankaya AB. Custom-made Subperiosteal Implants: A Finite Element Analysis on Monoblock and Dual Implant Systems in Atrophic Maxilla. Int J Med Sci. 2023;20(13):1755–62.

Vaira LA, Biglio A, Roy M, Salzano G, Troise S, Abbate V, et al. Full-arch rehabilitation of severely atrophic maxilla with additively manufactured custom-made subperiosteal implants: A multicenter retrospective study. J Craniomaxillofac Surg. 2024;52(9):991–8.

Łoginoff J, Majos A, Elgalal M. Long-term clinical results of additively manufactured subperiosteal implants for the treatment of the severely atrophic maxilla. J Craniomaxillofac Surg. 2025.

Anitua E, Eguia A, Staudigl C, et al. Clinical performance of additively manufactured subperiosteal implants: a systematic review. Int J Implant Dent. 2024;10(1):4.

Van den Borre C, De Neef B, Loomans NAJ, Rinaldi M, Nout E, Bouvry P, et al. Soft Tissue Response and Determination of Underlying Risk Drivers for Recession and Mucositis after AMSJI Implantation in the Maxilla. Int J Oral Maxillofac Implants. 2024;39(2):302–9.

Zielinski R, Okulski J, Piechaczek M, Łoś J, Sowiński J, Sadowska-Sowińska M, et al. Five-Year Comparative Study of Zygomatic and Subperiosteal Implants: Clinical Outcomes, Complications, and Treatment Strategies for Severe Maxillary Atrophy. J Clin Med. 2025;14(3):661.

Vaira LA, Biglio A, Favro A, Salzano G, Abbate V, Lechien JR, De Riu G. Implant-prosthetic rehabilitation of the atrophic posterior mandible with additively manufactured custom-made subperiosteal implants: a cohort study. Int J Oral Maxillofac Surg. 2024;53(6):533–40.

Van den Borre C, Otero JJ, Loomans N, Samama M, Lempert J, Baltensperger M, et al. Retrospective analyses of additively manufactured subperiosteal jaw implants in the mandible. J Craniomaxillofac Surg. 2025;53(7):905–10.

Onică N, Budală DG, Baciu E-R, Onică CA, Geleţu GL, Murariu A, Balan M, Pertea M, Stelea C. Long-Term Clinical Outcomes of 3D-Printed Subperiosteal Titanium Implants: A 6-Year Follow-Up. J Pers Med. 2024;14(5):541.

Chapter 3 — The HUG® Concept

A Nine-Pillar Framework

A subperiosteal implant is not simply a device — it is a system. When complications arise, the cause is rarely a single isolated problem. More often, it reflects a gap in the conceptual framework: inadequate surgical protocol, insufficient biological support, poor tissue management, or compromised prosthetic design. This is why we speak of a concept, not just an implant.

3.1 Why Does Tissue Recession Occur? The Biological Space Concept

Despite the absence of published studies specifically defining the biological width around subperiosteal implants, clinical observations and histological evidence allow us to propose a plausible explanation for the gingival recession frequently observed in this context. The histological section shown below, obtained from an animal model of a subperiosteal implant, illustrates this challenge with remarkable clarity. Depending on clinical conditions, surgical management, and patient-related factors, the external surface of the implant may heal within two distinct histological environments.

Figure 3.1 — Histological cross-section in an animal model of a subperiosteal implant. Two contrasting situations are illustrated. Left: no vascularised support above the arm — direct contact with soft tissue only — high recession risk. Right: thin layer of newly formed bone above the arm — vascularised support for the overlying gum — lower recession risk and favourable conditions for an intraosseous subperiosteal implant outcome.

On the left side of this section, one can observe that above the implant arm there is only soft tissue — no vascularised bony support. In this configuration, the gum rests directly on metal. There is no underlying bone to provide vascular nutrition or structural stability to the overlying mucosa. This is the anatomical basis for recession: a soft tissue with no stable foundation will tend to migrate apically over time, exposing the implant arm.

On the right side, a thin but critical layer of newly formed bone has developed above the arm. This regenerated bone provides vascularised support for the gum and eliminates direct contact between

the soft tissue and the titanium surface. In this situation, recession risk is substantially reduced. This is exactly the intraosseous subperiosteal implant concept: embedding the implant within bone regeneration so that the overlying gingiva is supported, not floating on metal.

These two situations are not random outcomes; they are the direct consequence of the surgical and biomaterial-related decisions made at the time of implant placement. The entire HUG® Concept is designed to systematically produce the desired outcome: an intraosseous-subperiosteal implant.

3.2 The Two Guiding Goals

Behind all nine pillars lies a simple clinical objective: better soft-tissue integration, and long-term clinical reliability. Every pillar either reduces the risk of gingival recession, promotes osseointegration, or ensures that the implant and prosthetic restoration withstand the mechanical demands of a lifetime of masticatory function. The Two Goals of the HUG® Concept:

1. Better soft-tissue integration — reducing gingival recession
2. Long-term clinical reliability — mechanical and biological predictability

Every pillar addresses one or both of these goals.

3.3 The Nine Pillars

#	Pillar	Clinical Purpose
1	**Implant Design & Structure**	Optimises biological response through gyroid lattice geometry
2	**Surface Treatment & Anodization**	Enhances osseointegration, cell behaviour, and soft tissue sealing
3	**Biomechanical Studies**	Validates design safety through Finite Element Analysis — for each patient individually
4	**Pterygoid Anchorage**	Improves force distribution; opposes cantilever mechanics in the maxilla
5	**Bone Cutting Guide**	Ensures precise implant positioning within the bony crest
6	**Tissue Management**	Promotes bone regeneration above implant; prevents gingival recession
7	**Implant Replicas**	Allows surgical rehearsal and pre-operative verification
8	**The Prosthesis**	Delivers a definitive restoration from the day of surgery
9	**Digital Workflow**	Integrates all steps within a validated patient-specific digital platform

3.4 What Happens Without the Framework

The broader evidence base confirms this picture. We already provided an overview of the available evidence in Chapter 2 through the literature review. Here are some additional findings. A systematic review by Anitua and colleagues (2024), including 13 studies, 227 patients, and 227 additively manufactured subperiosteal implants with a weighted mean follow-up of 21.4 months, reported a survival rate of 97.8% — a reassuring figure. However, the complication profile was substantial: 25.6%

of implants presented partial soft tissue exposure, 5.3% of patients developed persistent soft tissue infection, and the authors concluded that soft-tissue related complications represented the primary clinical challenge of the technology. The authors explicitly called for further studies to assess medium- and long-term behaviour.

Taken together, these data convey a consistent message: modern additively manufactured subperiosteal implants demonstrate good short-term survival. The limiting factor is not only mechanical — it is also biological, and specifically soft-tissue related.

Clinical Note If you place a subperiosteal implant by simply opening a flap, fixing the implant, and closing, the system may work — but expect around 25 % or more soft-tissue recession. Following the HUG® Concept should significantly reduce this complication rate.

References

De Moor RJG, Vercruyssen M, Duyck J. Finite element analysis of additively manufactured subperiosteal jaw implants in the atrophic maxilla. Int J Oral Maxillofac Implants. 2022;37(4):789–801.

Vaira LA, Biglio A, Favro A, Salzano G, Abbate V, Lechien JR, De Riu G. Implant-prosthetic rehabilitation of the atrophic posterior mandible with additively manufactured custom-made subperiosteal implants: a cohort study. Int J Oral Maxillofac Surg. 2024 Jun; 53(6):533-540.

Anitua E, Eguia A, Staudigl C, Alkhraisat MH. Clinical performance of additively manufactured subperiosteal implants: a systematic review. Int J Implant Dent. 2024 Feb 5;10(1):4.

Van den Borre C, Otero JJ, Loomans N, Samama M, Lempert J, Baltensperger M, Termont A, Castro R, Mommaerts MY. Retrospective analyses of additively manufactured subperiosteal jaw implants in the mandible. J Craniomaxillofac Surg. 2025 Jul;53(7):905-910.

Chapter 4 — Pillar 1 — Implant Design and Structure

Growing bone inside a titanium structure is not simple — it is one of the biggest challenges in subperiosteal implantology. The macroscopic architecture of the implant determines whether the biological conditions for osseointegration can exist at all. No surface treatment or biomaterial can compensate for an implant body that is biologically inert at the macroscopic scale.

4.1 The Case for Lattice Structures

Solid titanium presents a barrier to bone growth rather than an invitation. It does not allow cell penetration, provides no surface area for vascularisation, and creates a stress-shielding environment that can suppress rather than stimulate bone formation. Lattice structures — three-dimensional porous architectures widely used in orthopaedic and maxillofacial surgery — offer a fundamentally different biological environment. Their mechanical and morphological characteristics actively favour cell penetration, vascular ingrowth, and osseointegration.

4.2 The Gyroid TPMS Structure

Among hundreds of possible lattice geometries, the HUG® Concept selected the gyroid TPMS (Triply Periodic Minimal Surface) structure. The gyroid offers three clinically relevant advantages: excellent mechanical resistance to compressive and bending forces; porosity (at 50%) closely mimicking cancellous bone; and a fully interconnected pore network allowing fluid flow, vascular penetration, and cell migration throughout the entire implant body.

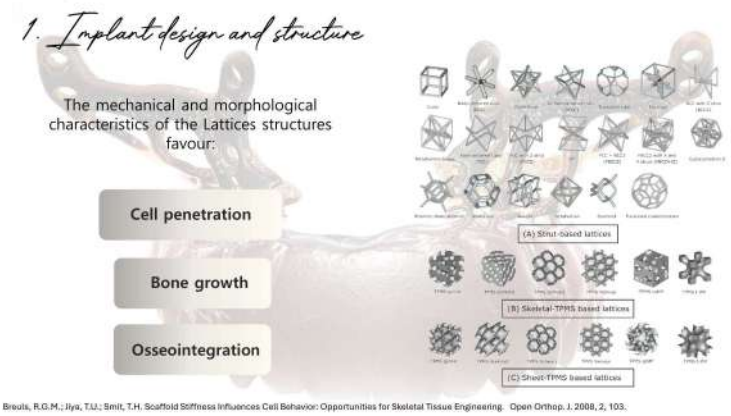


Figure 4.1 — Different Lattice architecture types (Strut-based, TPMS Skeletal and TPMS Sheet). The mechanical and morphological characteristics of lattice structures favour cell penetration, bone growth and osseointegration. Adapted from Breuls et al., 2008.

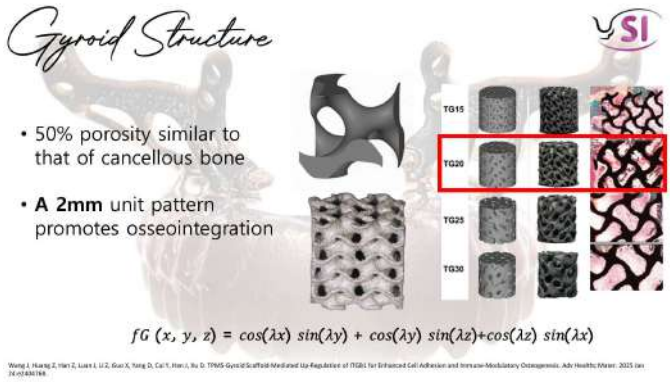


Figure 4.2 — TPMS Gyroid structure: mathematical representation and visual rendering. A 50% porosity with a 2 mm unit cell size optimally promotes cell penetration and osseointegration. Adapted from Wang et al., 2025.

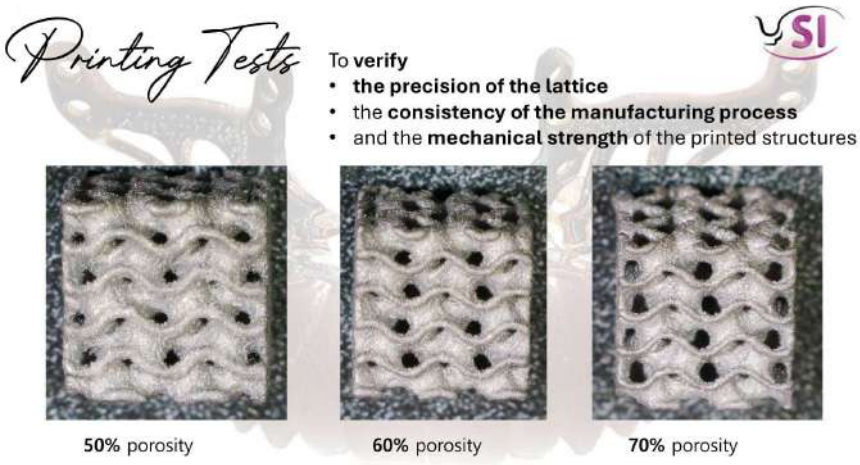


Figure 4.3 — Printing tests of the gyroid structure at 50%, 60% and 70% porosity to verify dimensional precision, manufacturing consistency and mechanical strength of the printed structures.

Figure 4.4 — Comparison of Gyroid Lattice designs at 50% and 70% porosity on a maxillary HUG® implant. The 50% version delivers the optimal balance between biological performance and mechanical strength; the 70% version was rejected following biomechanical validation.

The Critical Role of Pore Size

Choosing the gyroid topology is only part of the equation. The scale of the lattice pattern — specifically the unit cell size — has a profound effect on biological performance independent of topology. Studies show that a 2 mm cell size offers optimal conditions for cell penetration, vascularisation, and new bone formation. This is not a design aesthetic — it is a biological decision.

4.3 Porosity Selection: 50% vs 70%

The HUG® Concept uses 50% porosity. The 70% structure offered superior theoretical biological performance but proved mechanically inadequate, approaching the elastic limit of titanium under maximum functional loading. The 50% porosity achieves the critical balance: adequate porosity for vascular and cell infiltration, with sufficient mechanical strength to resist masticatory forces. The 70% version was rejected.

4.4 Design and Printing Validation

Selecting the optimal lattice was only the beginning. The design team conducted multiple design iterations and printing tests to verify: dimensional precision of the printed lattice; manufacturing consistency across print batches; and mechanical strength of printed structures. This validation confirmed that what performs optimally in simulation also performs optimally in clinical reality.

4.5 Implant Anatomy

Maxillary Design

For maxillary cases, the main frame branches outward to three wings: toward the zygomatic process, toward the pyriform opening edge, and toward the pterygomaxillary suture. These fixation areas are chosen for their low bone resorption rates and long-term anatomical stability.

Mandibular Design

For mandibular cases, the lattice sits on the vestibular surface. The main body includes a vestibular lattice and a lingual headband. Extensions reach the posterior vestibular trigone, the outer oblique line, and the mandibular symphysis anterior to the mental foramen.

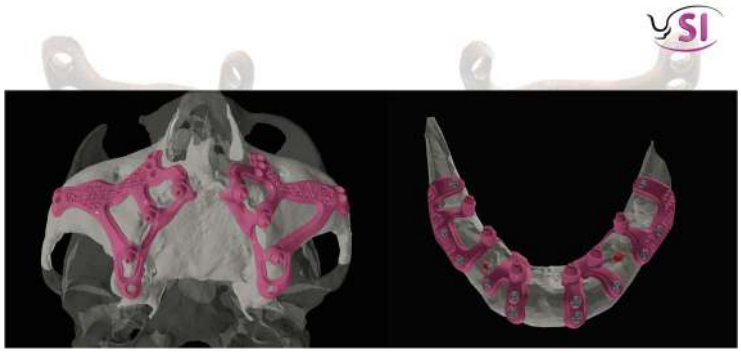


Figure 4.5 — Examples of maxillary (left) and mandibular (right) custom-made digital subperiosteal implant designs. Each implant is individually designed from CBCT-derived 3D models to match the patient's anatomy and provide stable fixation in cases of severe jaw atrophy.

Prosthetic Abutment and Six-Pillar Design

The prosthetic abutments are milled after printing to achieve the dimensional accuracy required for the MUA connection. The standard configuration uses six prosthetic abutments for full-arch treatment: optimal force distribution, reduced screw overload, and a salvage option (the system can function on five pillars if one is compromised). Four-pillar designs require thicker arms — increasing recession risk — and cannot be rescued if a pillar fails.

Clinical Note PMMA replicas of the implant and a pre-drilled resin jaw model are included in every HUG® package. Always verify that the replica and model perforations match perfectly before surgery. Never contaminate or open the sterile titanium implant unnecessarily.

References

Wang J, Huang Z, Han Z, et al. TPMS-Gyroid Scaffold-Mediated Up-Regulation of ITGB1 for Enhanced Cell Adhesion and Immune-Modulatory Osteogenesis. Adv Healthc Mater. 2025;e2404768.

Breuls RGM, Jiya TU, Smit TH. Scaffold Stiffness Influences Cell Behavior. Open Orthop J. 2008;2:103.

Kundakcioglu A, Demir T, Yilmaz B. Minimum implant thickness for custom subperiosteal implants. J Prosthet Dent. 2023;129(3):452–9.

Chapter 5 — Pillar 2 — Surface Treatment and Anodization

Pillar 1 defines the macroscopic architecture. Pillar 2 operates at the microscopic and nanoscopic scale — at the interface between titanium and the first biological molecules, cells, and tissues that will determine integration or failure. Anodic oxidation of titanium is not new in implantology; what is new is its application to the complex three-dimensional surfaces of a gyroid lattice, with a deliberate choice of oxide thickness and colour.

5.1 What Is Anodization?

Anodization creates a controlled TiO_2 oxide layer on the titanium surface via an electrochemical process. The titanium implant is immersed in an electrolytic bath; applied voltage controls the thickness of the oxide layer; and the thickness determines the implant's colour through thin-film light interference. This colour-voltage relationship is predictable but technically challenging to maintain consistently across the complex surfaces of a lattice structure.

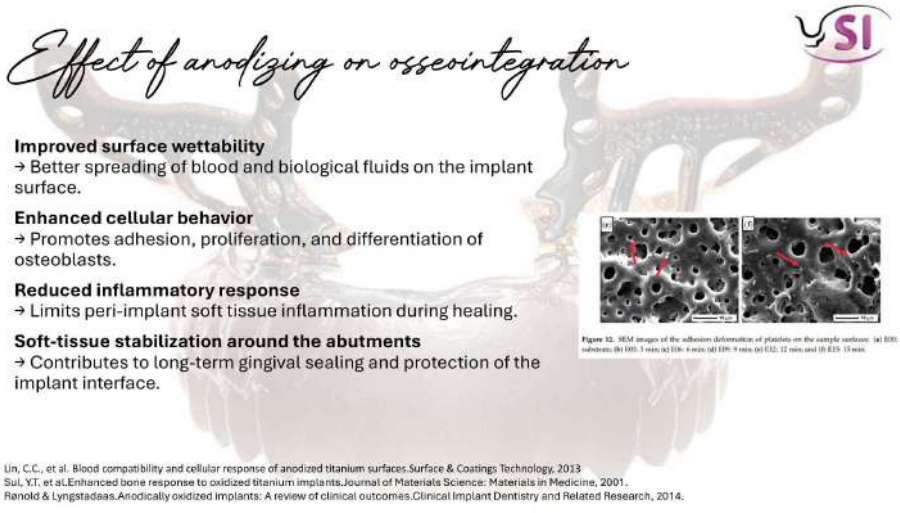


Figure 5.1 — Effects of anodization on osseointegration: improved surface wettability, osteoblast stimulation (adhesion, proliferation, differentiation), reduced peri-implant inflammatory response, and soft-tissue stabilisation around prosthetic abutments. Adapted from Lin et al., 2013; Sul et al., 2001.

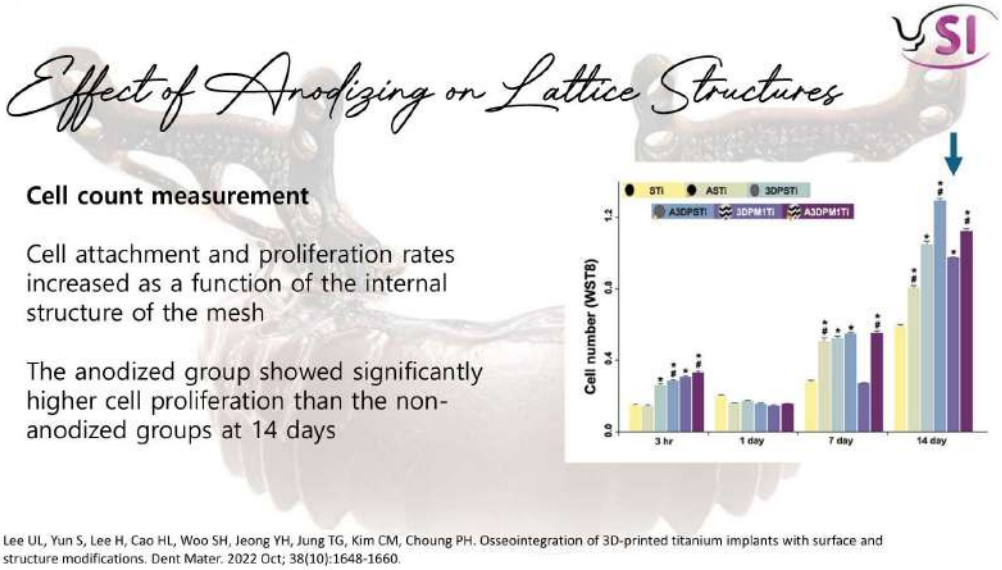


Figure 5.2 — Effect of anodization on 3D-printed Lattice structures: cell attachment and proliferation rates increase as a function of the internal mesh structure. The anodized group showed significantly higher cell proliferation than non-anodized groups at 14 days. Adapted from Lee et al., 2022.

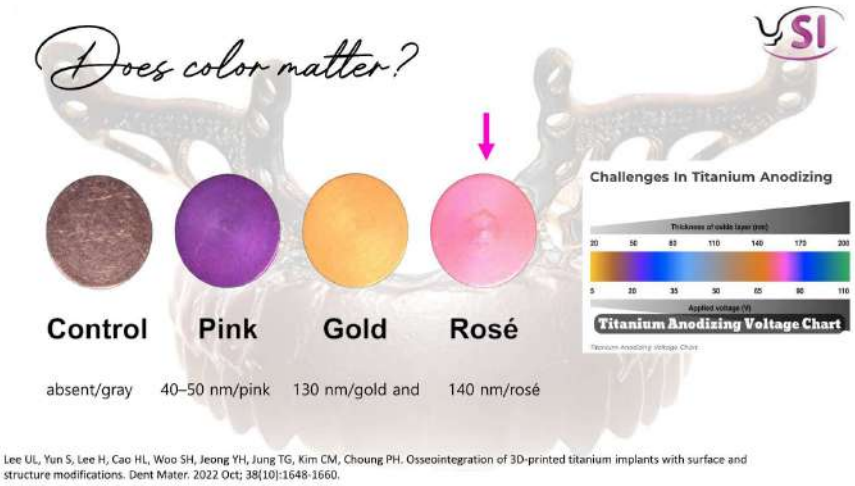


Figure 5.3 — Clinical significance of anodization colour: four conditions tested (Control/grey, Pink 40–50 nm, Gold 130 nm, Rosé 140 nm). The TiO_2 oxide thickness spectrum and corresponding anodization voltages (Titanium Anodizing Voltage Chart). Adapted from Lee et al., 2022.

Figure 5.4 — Clinical benefit of pink anodization: in the event of gingival recession, the pink tint of the implant considerably reduces the aesthetic impact compared to standard silver metal.

5.2 Biological Effects of Anodization

Anodization affects osseointegration through four distinct mechanisms. First, improved surface wettability: blood and biological fluids spread more rapidly across the surface in the critical first moments after placement, accelerating the protein adsorption cascade. Second, enhanced cellular behaviour: anodised surfaces promote osteoblast adhesion, proliferation, and differentiation. Third, reduced inflammatory response, creating a more stable healing environment. Fourth, soft tissue stabilisation around the abutments — contributing to a long-term gingival seal.

Anodization on Lattice Structures

These effects are amplified on the internal geometry of a gyroid lattice. An in vitro study measuring cell proliferation directly on 3D-printed titanium mesh structures found that the anodised group showed significantly higher cell proliferation than non-anodised controls at 14 days — the most clinically relevant time point for early osseointegration. Anodization and lattice structure have synergistic biological effects.

5.3 In Vivo Evidence

A study by Cho et al. compared mechanical stability of mini-implants with three surface treatments in a dog model: machined (control), SLA, and SLAO (SLA + anodic oxidation). The SLAO group showed the highest maximum removal torque — a direct measure of osseointegration quality — significantly exceeding both the machined and SLA groups.

5.4 Why Rosé? A Dual Rationale

Biological Rationale

Among the different anodization colours, the rosé shade (140 nm oxide layer) showed superior performance in osteoblast culture studies: significantly higher Type I procollagen production and better cell viability compared to gold and control surfaces. Type I collagen is the structural scaffold upon which mineralisation occurs.

Clinical and Aesthetic Rationale

Gingival recession remains the most common complication of subperiosteal implants. When recession occurs, the visual appearance of the exposed metal becomes a significant aesthetic concern. A pink-anodised implant blends with surrounding gingival tissue, dramatically reducing the aesthetic impact of recession. Yellow anodization, though technically easier to produce consistently, lacks this clinical benefit.

Clinical Note Choosing rosé anodization is a form of biological insurance: it does not prevent recession, but it significantly reduces the aesthetic consequences if recession occurs. This benefit extends beyond biology to patient satisfaction and long-term quality of life.

References

Lee UL, Yun S, Lee H, et al. Osseointegration of 3D-printed titanium implants with surface and structure modifications. Dent Mater. 2022;38(10):1648–60.

Lin CC, et al. Blood compatibility and cellular response of anodized titanium surfaces. Surf Coat Technol. 2013.

Sul YT, et al. Enhanced bone response to oxidized titanium implants. J Mater Sci Mater Med. 2001.

Cho IS, Kim SK, Chang YI, Baek SH. In vitro and in vivo mechanical stability of orthodontic mini-implants. Angle Orthod. 2012;82(4):611–7.

Chapter 6 — Pillar 3 — Biomechanical Studies

Biology and anodization alone do not make a safe implant. A subperiosteal implant that osseointegrates but then fractures under masticatory load is a treatment failure by any standard. Pillar 3 addresses mechanical validation — both at the population level during development and at the individual patient level for every case placed.

6.1 The Role of Finite Element Analysis

Finite Element Analysis (FEA) is a mathematical modelling technique that simulates the mechanical behaviour of complex three-dimensional structures under applied loads. For the HUG® Concept, FEA serves two distinct purposes: global design validation confirming the design is mechanically sound before clinical use; and patient-specific validation for every individual implant, because every patient presents a unique combination of anatomy, bone quality, and occlusal forces.

Clinical Note Few companies currently perform patient-specific finite element analysis for every subperiosteal implant case. This feature directly improves safety for surgeon and patient, and the analysis report can be presented to the patient as part of the informed consent process.

6.2 Literature: Monobloc vs. Dual Design

A study by Ayhan and Cankaya directly compared monobloc and dual design approaches. The dual design showed better stress distribution and lower peak stresses across all tested loading scenarios, with all values remaining below the elastic limit of titanium. Additionally, manufacturing two smaller implants is technically easier and less prone to distortion than printing a single large monobloc structure. All modern subperiosteal systems — including HUG® — therefore use a dual design.

6.3 The HUG® Thickness Study

A key design challenge is the trade-off between implant thickness and soft tissue management. Thicker arms are mechanically safer; thinner arms reduce recession risk. To resolve this with data, the Subperiosteal Institute conducted a dedicated FEA study evaluating four thicknesses (1.2–1.5 mm) in collaboration with the Laboratoire de Biomécanique Appliquée, Université Gustave Eiffel, Aix-Marseille Université, GLAD Medical, and Biotech Dental.

Study Design

The model included cortical bone (elastic), the HUG® implant (elastoplastic, Ti Grade 23), fixation screws (elastic), and prosthetic bridge (elastic). A unilateral vertical load of 1,000 N simulated

maximum bruxing force — the most demanding clinical scenario. Three criteria were evaluated: prosthetic displacement, von Mises stress in the implant, and bone tissue strain.

Figure 6.1 — Finite element analysis (FEA): mathematical models enabling three-dimensional analysis of Von Mises stress distribution induced in bone. Conducted in collaboration with the Laboratoire de Biomécanique Appliquée (LBA), Université Gustave Eiffel and Aix-Marseille Université.

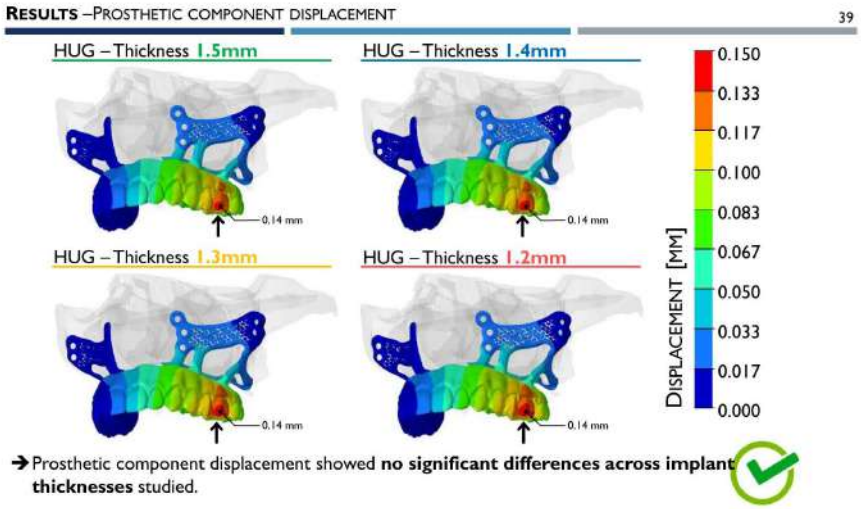


Figure 6.2 — Prosthetic component displacement results: no significant difference across the four thicknesses tested (1.2 to 1.5 mm) — constant displacement of 0.14 mm. Implant thickness does not affect the secondary stability of the prosthesis.

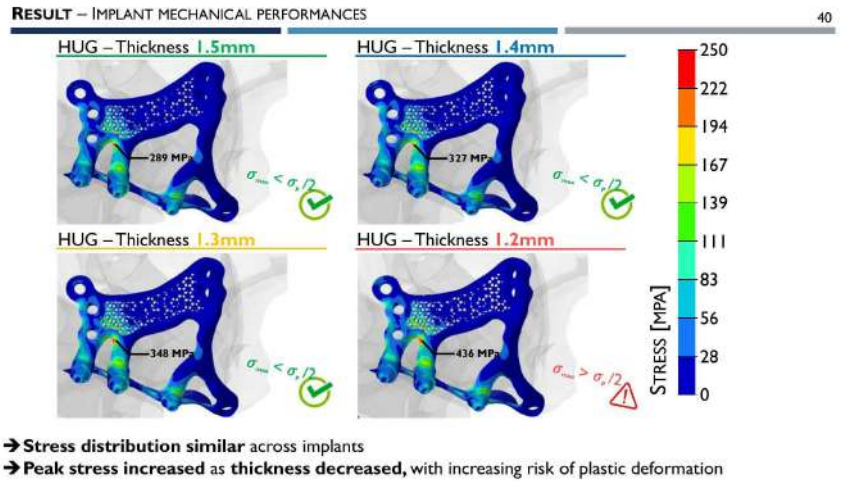


Figure 6.3 — Implant mechanical performance by thickness: Von Mises peak stress increases as thickness decreases. Thicknesses of 1.5 mm (289 MPa) and 1.4 mm (327 MPa) remain below the safety threshold (σp/2 = 397 MPa). The 1.2 mm thickness (436 MPa) exceeds this threshold and is excluded.

Results

Prosthetic displacement was identical across all four thicknesses (0.14 mm), confirming that thickness does not affect secondary stability within this range. Bone strain remained below the 4,000 με physiological threshold in all configurations. However, peak implant stress increased as thickness decreased: at 1.2 mm, it exceeded the safety threshold (436 MPa vs. 397.5 MPa), indicating a risk of plastic deformation under maximum bruxing forces.

6.4 Recommendation: 1.5 mm — Our Clinical Choice

The minimum recommended arm thickness based on static FEA findings is 1.4 mm. However, for the HUG® implant, we have chosen a standard thickness of 1.5 mm. It is also important to consider that the polishing process performed during implant manufacturing removes a certain amount of material from the implant surface. By selecting an initial thickness of 1.5 mm, we ensure that, even after polishing, the implant retains a minimum thickness of 1.4 mm, thereby preserving its mechanical strength and structural integrity. This choice maintains stress well below the safety threshold, provides a superior safety coefficient, and still remains thin enough to minimize soft tissue compression and reduce the risk of recession.

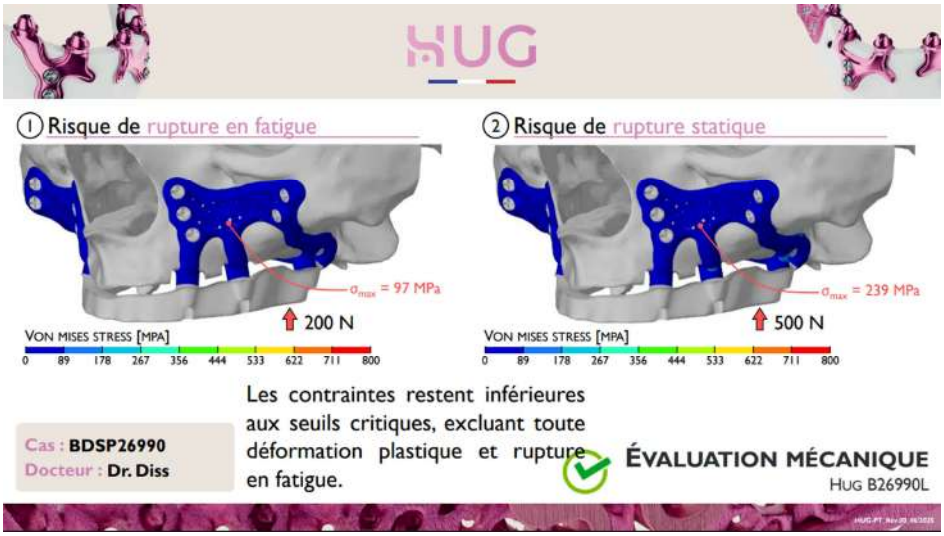


Figure 6.4 — Patient-specific finite element analysis delivered with every HUG® implant. Left: fatigue failure risk assessment — implant subjected to 200 N repeated forces daily for 15 years (σmax = 97 MPa). Right: static rupture risk — maximum unilateral load of 500 N (σmax = 239 MPa). All stresses remain below critical thresholds, confirming the absence of plastic deformation and fatigue fracture risk.

6.5 Patient-Specific Finite Element Analysis: A Safety Guarantee for Every Case

Finite element analyses allow us to simulate loading conditions and analyse how each implant behaves under stress. Performing a dedicated finite element analysis for every single case is a major clinical advantage — it improves safety for both the surgeon and the patient, and provides documented mechanical validation that can be shared during the informed consent process.

Two types of analyses are performed for each HUG® implant. First, a fatigue failure risk assessment: the implant is subjected to repeated forces of 200 newtons, every day for 15 years, to evaluate whether cyclic loading could lead to progressive structural failure. Second, a static rupture risk assessment: the implant is subjected to a maximum unilateral static load of 500 newtons, to determine whether any plastic deformation occurs under extreme occlusal force.

Implants are only delivered if they pass both tests. This means that every patient treated with a HUG® implant receives not only a custom-designed device adapted to their anatomy, but also a mathematically validated guarantee that it will withstand the mechanical demands of a clinical lifetime.

References

Ayhan M, Cankaya AB. Custom-made Subperiosteal Implants: A Finite Element Analysis on Monoblock and Dual Implant Systems in Atrophic Maxilla. Int J Med Sci. 2023;20(13):1755–62.

Subperiosteal Institute / LBA / Université Gustave Eiffel / GLAD Medical / Biotech Dental. HUG® Design Evaluation — Numerical Assessment: Influence of Thickness on Implant Mechanical Performance. Internal report, May 2025.

De Moor E, et al. Biomechanical evaluation of custom subperiosteal implants. Int J Oral Maxillofac Surg. 2022.

Chapter 7 — Pillar 4 — Pterygoid Anchorage

The maxilla is a biomechanically challenging site. Less cortical than the mandible, prone to resorption, and subject to large anterior cantilever forces from the prosthesis, it demands an anchorage strategy beyond the classical nasal and zygomatic anchors. Pterygoid anchorage — the fourth pillar of the HUG® Concept — changes the biomechanical equation.

7.1 Why the Maxilla Is Different

The maxilla presents a unique set of mechanical challenges for subperiosteal implants. Its lower degree of corticalisation compared to the mandible means that fixation screws engage less dense bone, reducing primary stability. More critically, the large anterior prosthetic cantilever — made necessary by the degree of anterior bone resorption in patients requiring subperiosteal rehabilitation — generates significant tipping and rotation forces on the implant body.

These forces are not evenly distributed across all fixation points. The posterior anchors bear a disproportionate share of the tipping load generated by the anterior cantilever. In the absence of posterior anchorage in dense bone, this creates a mechanical vulnerability that cannot be fully addressed by nasal and zygomatic anchor points alone.

7.2 The Anatomy of Pterygoid Anchorage

The pterygomaxillary region — specifically the pterygoid plates of the sphenoid bone — contains dense cortical bone that is largely unaffected by the maxillary atrophy that characterises Cawood-Howell Class V and VI patients. This anatomical constancy is not an accident: the pterygoid plates do not participate in alveolar bone remodelling, and their density is maintained regardless of the degree of maxillary atrophy.

The pterygoid anchorage screw penetrates the pterygomaxillary suture and engages the cortex of the pterygoid plate. This provides a posterior, superior, and medial fixation point that completes a triangular support structure — a levitation triangle — with the zygomatic process anchor anterolaterally and the pyriform opening edge anteromedially. Within this triangle, forces are distributed across all three cortical anchor points, significantly reducing peak stress at each individual fixation site.

7.3 Biomechanical Evidence

In a conventional subperiosteal implant design, the most posterior portion of the framework frequently rests on the floor of the maxillary sinus. However, this area may consist of extremely thin bone, sometimes only a fraction of a millimeter thick, providing limited support and resistance to functional loading.

In contrast, the Intraosseous concept extends posteriorly into the pterygoid region, allowing the implant to rest on and be anchored within one of the densest cortical bone areas of the maxilla. This strategy improves primary stability, enhances load distribution, and provides a more predictable biomechanical environment for immediate loading. By relying on strong cortical anchorage rather

than fragile sinus-floor bone, the implant benefits from a significantly more stable and durable foundation.

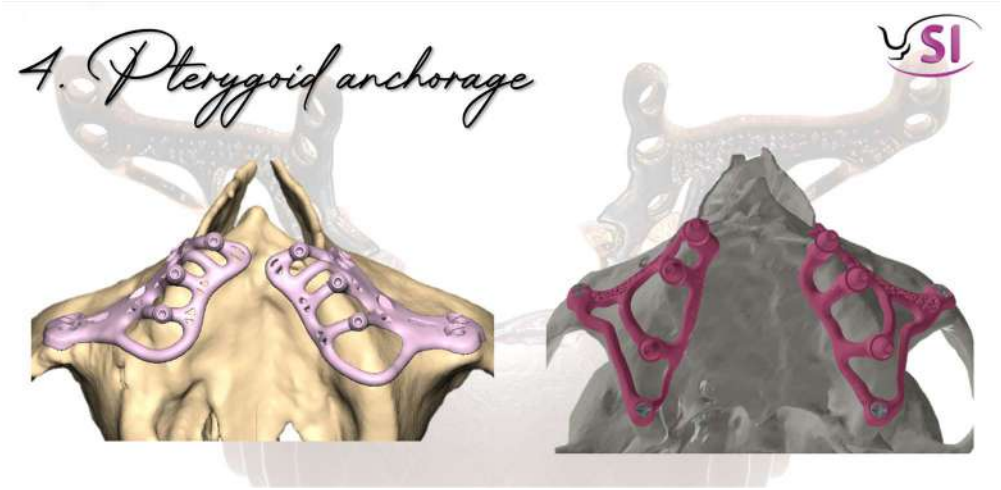


Figure 7.1 — Comparison between a conventional subperiosteal implant design (left) and a design incorporating pterygoid anchorage (right). While conventional designs rely primarily on the thin posterior maxillary bone, pterygoid anchorage allows fixation in dense cortical bone, improving mechanical stability and load distribution.

The biomechanical rationale for pterygoid anchorage in subperiosteal implants has been confirmed by finite element analysis. The dense anatomy of the pterygomaxillary region is well established in the literature on pterygoid implants for conventional endosseous rehabilitation. Multiple FEA studies confirm that anchorage in this area improves load distribution and reduces peak stresses at the implant–bone interface in conventional implant.

Pterygoid anchorage provides three major biomechanical advantages for subperiosteal implant rehabilitation. First, it enlarges the implant support triangle, increasing the overall footprint of the framework and improving stability. Second, the posterior extension helps balance anterior functional forces, reducing cantilever effects and distributing occlusal loads more evenly across the implant. Finally, fixation within the dense cortical bone of the pterygoid region enhances resistance to posterior masticatory forces, where chewing loads are greatest. Together, these features contribute to a more stable and predictable biomechanical environment for long-term function.

Clinical Note

No other company currently offers pterygoid anchorage as part of its subperiosteal implant system. In the HUG® Concept, it is mandatory for maxillary full-arch cases. The screw engages the pterygoid plate through the pterygomaxillary suture and must be carefully planned using CBCT imaging.

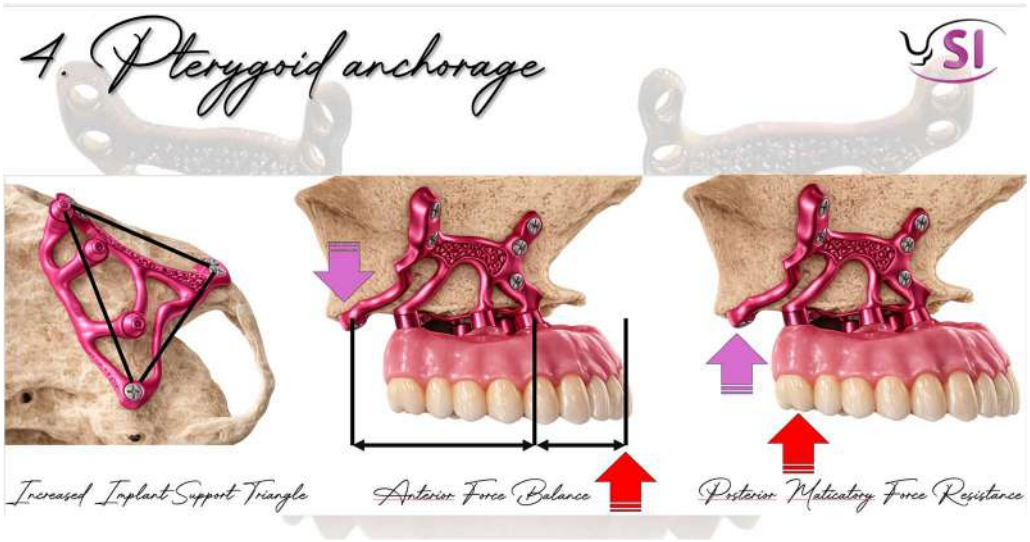


Figure 7.2 — Published case report of pterygoid anchorage in subperiosteal implants (Diss et al., Cureus 2025, PMID 40458381). The paper confirms the biomechanical rationale, surgical feasibility, and excellent patient outcome in a full-arch maxillary case with extreme atrophy.

7.4 The Guided Pterygoid Screw — A Practical Innovation

Placing a pterygoid screw accurately in the posterior maxilla is technically demanding. The anatomy is narrow, access is limited, and the safety zone — while generous — must be consistently reached. Free-hand placement carries a risk of malposition.

To address this, the HUG® Concept integrates a half-tube guidance system into the prosthetic bridge itself. The drill follows a pre-planned trajectory defined during digital design, guided through a partial tube that provides directional control without requiring a full-sleeve guide. The half-tube design was deliberately chosen over a full tube for a practical reason: in the posterior maxilla, a full sleeve is difficult to insert and remove, particularly when the drill chuck — which is larger than the working portion of the drill — must pass through.

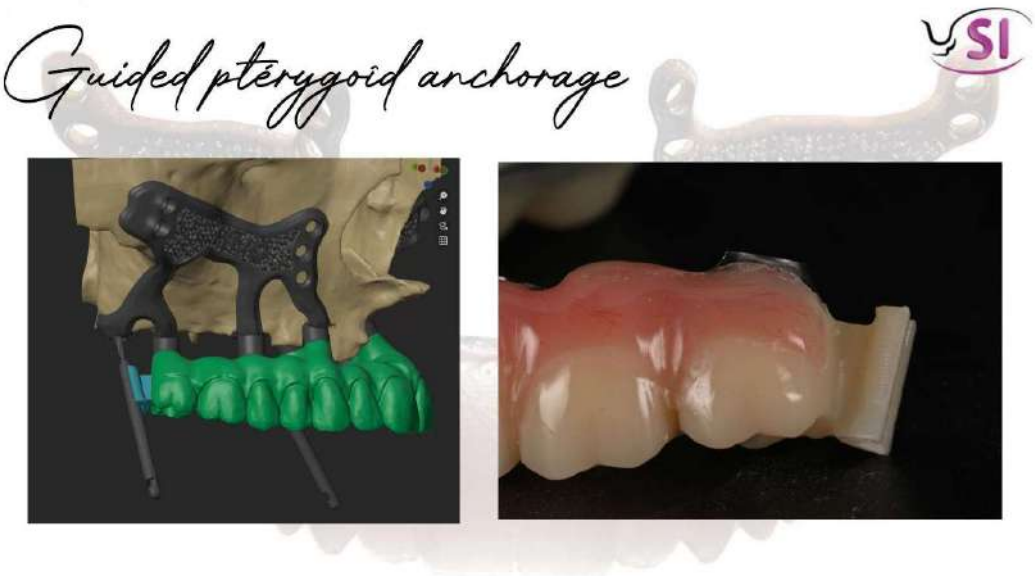


Figure 7.3 — Guided pterygoid anchorage: digital planning view showing drill trajectory through the prosthetic bridge guide (left). Intraoral photograph of the PMMA bridge with integrated half-tube guide for pterygoid drill guidance (right).

The half-tube configuration allows the surgeon to feel the tactile transition from trabecular to cortical bone, providing biological feedback during drilling. The entrance of the guide is flared to facilitate drill insertion and to guide the drill naturally into the correct trajectory. This design provides both guidance and tactile sensitivity.

The exit point of the pterygoid screw may be located between the medial and lateral pterygoid plates. However, to obtain the strongest possible anchorage, engagement of the cortical bone of the medial pterygoid plate is generally sought. As a result, the overall trajectory of the screw is usually directed from anterior to posterior, from lateral to medial, and from inferior to superior.

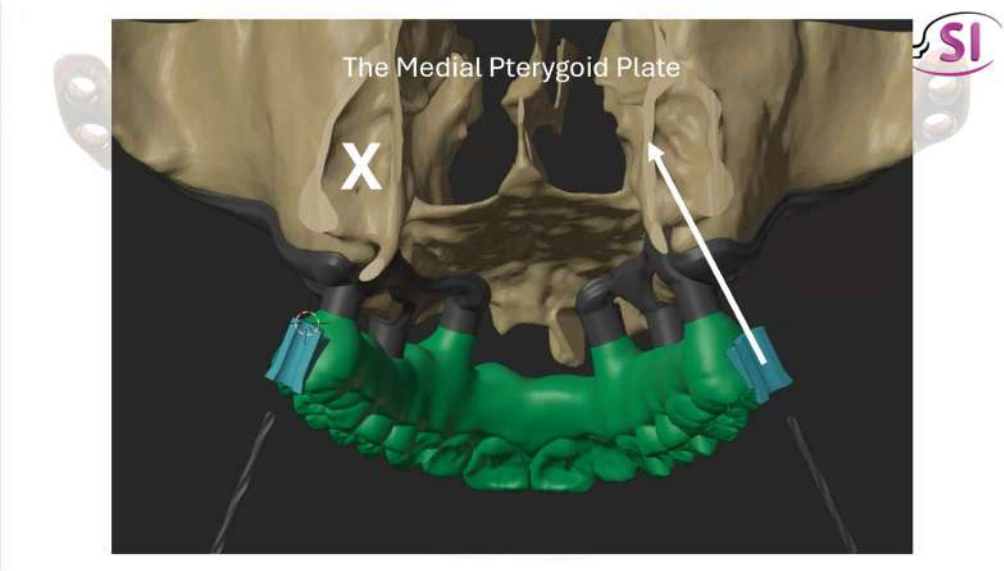


Figure 7.4 — Posterior view of the pterygoid guidance. On the left, the screw exits between the two pterygoid plates. On the right, the screw exits within the medial pterygoid plate, providing improved anchorage and enhanced mechanical stability.

7.5 Pre-operative Rehearsal with Replicas

Before surgery, the PMMA replica of the HUG® implant (Pillar 7) allows the surgeon to test the guidance system on the resin jaw model. The drill path through the guide can be verified, and the point where the drill tip exits at the pterygoid plate can be identified and confirmed to lie within the safe zone.

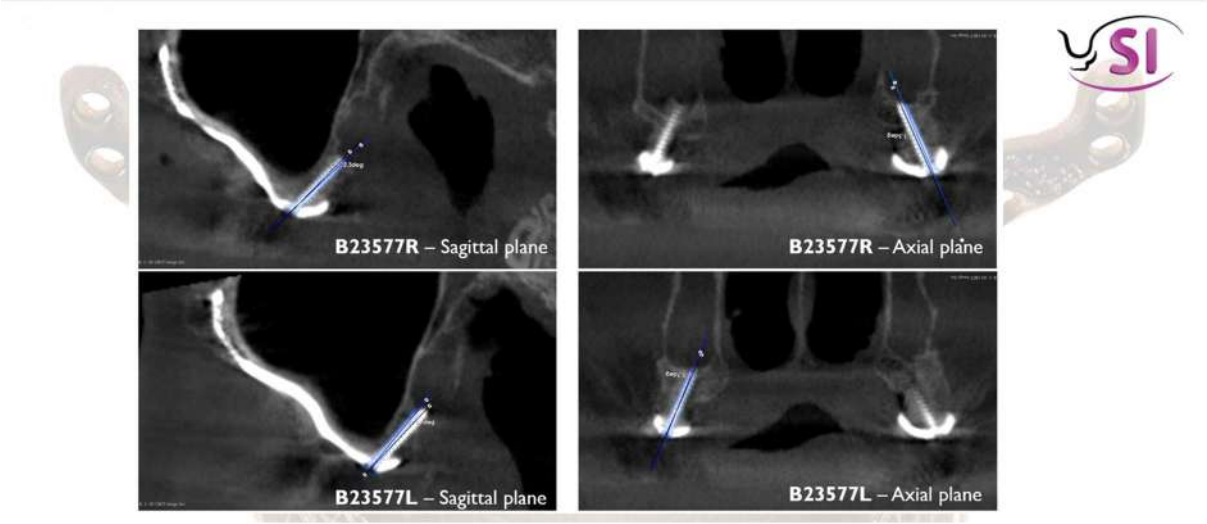
This rehearsal step is particularly important for the pterygoid anchorage, where the three-dimensional trajectory is difficult to visualize without simulation. The replica and resin model together transform an abstract digital plan into a tangible, verifiable physical rehearsal.

7.6 Clinical Accuracy Data

A matching analysis was performed between the postoperative CBCT dataset and the planned pterygoid anchorage screw positions to evaluate the accuracy of the guided placement protocol. The results demonstrate accuracy comparable to conventional guided implant surgery: angular deviation

below 4 degrees in all planes, and screw tip deviation below 1.5 mm. Given the generous dimensions of the pterygoid safety zone, this level of accuracy ensures reliable and safe placement in all planned cases.

This innovation represents a significant step toward making pterygoid anchorage a reliable, reproducible procedure accessible to clinicians without specialist pterygoid surgery training.



		B23577R	B23577L
Angle deviation [°]	*Sagittal Plane*	2,3°	3,7°
	Axial Plane	1,3°	1,7
Screw tip deviation [mm]	-	0,74mm	1,25mm

Figure 7.5 — Sagittal and axial CBCT views show the superimposition of the planned (blue) and actual postoperative screw positions on the right (B23577R) and left (B23577L) sides. Angular deviations ranged from 1.3° to 3.7°, while screw tip deviations remained below 1.5 mm, demonstrating the high accuracy and reproducibility of the guided pterygoid anchorage protocol.

References

Diss A, Lerebours A, Grébenval C, Birault L. Pterygoid Anchorage of Subperiosteal Implants: An Overview and Case Report. Cureus. 2025 Jun 1;17(6):e85175.

Manav ÖC, Üçok C, Kocamaz ÖF. Comparison of the Mechanical Stability of Different Implant Types in the Atrophic Maxilla of Patients With Bruxism Using Finite Element Analysis. J Oral Implantol. 2026 Apr 6;52(2):151-159.

Chapter 8 — Pillar 5 — Cutting Guide & Surgical Protocol

> *The surgical protocol is not simply the mechanical placement of an implant. It is the moment at which all the biological, mechanical, and digital work of Pillars 1 through 4 is either realised or lost. The cutting guide is the physical instrument through which the protocol achieves precision — embedding the implant into bone rather than leaving it exposed above the crest.*

8.1 The Evidence: Why Protocol Matters

The clinical literature on subperiosteal implants documents a clear relationship between surgical protocol and soft tissue outcomes. A multicenter study by Van den Borre and colleagues evaluating 40 maxillary cases with a mean follow-up of 2.5 years reported only one implant loss — an excellent survival result. However, gingival recession was observed in 65% of patients. A significant proportion of these recessions can be explained by an incision placed too far in the vestibular mucosa, as illustrated in the clinical photograph below. This leaves the keratinised gingival band displaced palatally after closure, depriving the abutments of any stable soft tissue coverage on the vestibular side.

The mandibular data tell a similar story. A larger multicenter study covering 40 mandibular implants in 19 patients over seven years (2017–2024) reported a 92.5% survival rate — three implants removed — but gingival recession in 32% of cases. These numbers are far better than the maxillary series but still represent a significant complication rate.

By contrast, an Italian multicenter cohort study by Vaira and colleagues evaluated 30 custom subperiosteal implants in 17 patients with mandibular atrophy over a mean follow-up of 22 months. The survival rate was 100%. No gingival recession was observed. This outcome was not explained by patient selection — the population had comparable levels of atrophy to the Van den Borre series. The explanation lies in the surgical approach.

8.2 The Cutting Guide: Precision Embedding

The critical difference between the two series could be the systematic use of a cutting guide to create a bone recess — a slot or crenel — that allows the implant body to sit within the cortical bone rather than resting on its surface. When the implant is embedded, the overlying periosteum and gingiva rest on a stable bony foundation rather than on metal. This difference in approach, including the possible use of a bone resection guide, may explain the superior soft tissue outcomes observed in the Italian cohort, though we cannot be certain this is the sole explanatory factor.

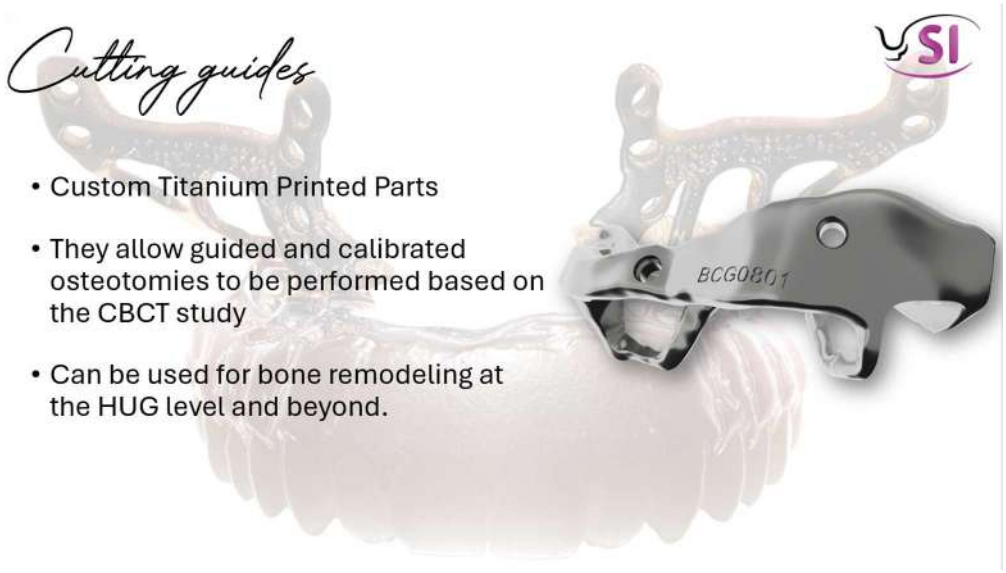


Figure 8.1 — Systematic use of a patient-specific bone reduction guide during subperiosteal implant surgery. The guide is designed from the digital treatment plan and allows precise bone reshaping before implant placement.

Biotech Dental® provides a custom surgical cutting guide for every HUG® case. The guide is designed in conjunction with the implant and the prosthetic bridge during the digital workflow (Pillar 9). It positions the bone cuts precisely, ensuring that the implant sits at the planned depth and angle within the crest.

8.3 Clinical Use of Bone Reduction Guides

Originally, bone reduction guides were developed to remove the residual alveolar bone and allow the implant to rest directly on the basal bone. This distinction is important because alveolar bone is more susceptible to physiological resorption over time, whereas basal bone is considerably more stable. Positioning a subperiosteal implant on basal bone therefore provides a more predictable and durable foundation.

For this reason, the initial purpose of bone reduction guides was to eliminate the remaining alveolar crest and expose the underlying basal bone before implant placement. In the HUG® Concept, however, we have expanded their role and systematically use a cutting guide even in situations where only basal bone remains. Beyond exposing stable bone, the guide allows the creation of a precisely planned bony recess in which the implant framework can be partially embedded.

The systematic use of patient-specific bone reduction guides improves implant stability, enhances soft tissue support, and increases the accuracy of implant seating. To achieve these objectives safely and reproducibly, the planned bone modifications must be transferred accurately from the virtual environment to the surgical field. This is the primary role of the cutting guide.

The cutting guide is designed simultaneously with the implant and prosthetic reconstruction during the digital workflow. It reproduces the exact amount of bone reduction required by the virtual plan and indicates the location, depth, and orientation of the osteotomy.

Several design principles must be respected:

- A safety distance of **2–3 mm from the maxillary sinus floor** should always be maintained.
- A minimum distance of **3 mm from the inferior alveolar nerve** should be preserved.
- Posterior support areas are incorporated into the guide whenever possible to facilitate stable positioning.
- The guide must remain sufficiently rigid to withstand surgical manipulation and, when necessary, gentle impaction during placement.
- Potential undercuts should be identified during planning and corrected before guide insertion.

Figure 8.2 — Surgical workflow using a custom bone reduction guide. Following digital planning, a patient-specific cutting guide is designed to reproduce the planned bone modifications during surgery.

After flap elevation and complete exposure of the bone surface, the guide is positioned on the jaw according to the planned anatomical reference points. Proper seating must be verified visually and manually before any bone reduction is initiated.

Once the guide is fully seated, the surgeon performs the planned osteotomy using piezosurgery or rotary instruments. The guide serves as a three-dimensional template that controls the extent of bone removal while protecting adjacent anatomical structures.

Following completion of the osteotomy, the guide is removed and the implant is tested. In most cases, the framework should seat passively within the prepared bony recess with minimal adjustment.

The use of a custom cutting guide offers several important advantages:

- By reproducing the virtual treatment plan precisely, the guide minimizes discrepancies between the planned and actual bone anatomy. This improves the passive fit of the implant and reduces the risk of pressure points on the surrounding soft tissues.
- Embedding the implant partially within the alveolar crest allows the periosteum and gingiva to rest on a stable bony foundation rather than directly over a metallic framework. This may reduce soft tissue tension and lower the risk of future exposure.

- Perhaps the most important benefit is standardization. The guide transforms a highly operator-dependent procedure into a reproducible surgical workflow, reducing variability between surgeons and improving treatment predictability.

Although cutting guides are used routinely, certain situations require special attention. In cases of extreme posterior maxillary atrophy, where only a very thin layer of bone remains beneath the sinus floor, extensive bone reduction may not be feasible. In these situations, the implant may be designed to rest directly on the residual bone without complete embedding.

Similarly, significant anatomical undercuts may require limited preliminary bone reshaping before guide insertion. The surgeon should always verify complete seating of the guide before proceeding with osteotomy.

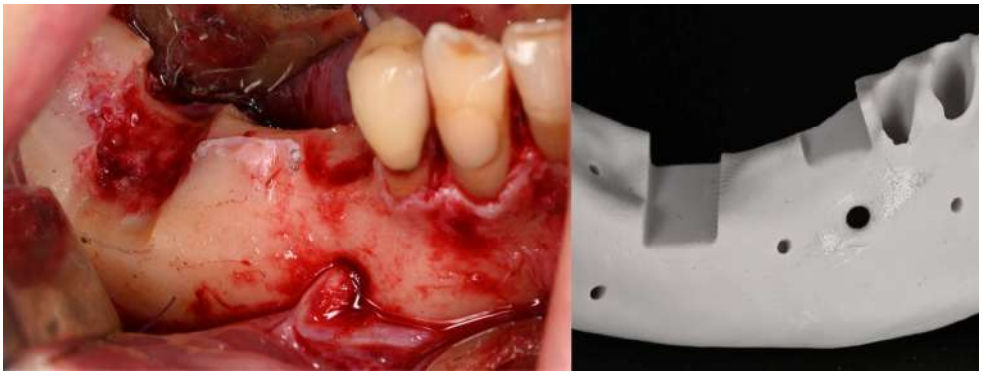


Figure 8.3 — Clinical validation of the bone reduction guide. The intraoperative photograph (left) and the corresponding 3D-printed guide (right) demonstrate the close agreement between the planned bone reduction and the surgical result.

The patient-specific bone reduction guide is a fundamental component of contemporary digital subperiosteal implantology. By accurately transferring the virtual surgical plan to the clinical environment, it improves implant fit, protects vital anatomical structures, enhances soft tissue management, and significantly increases the predictability and reproducibility of the procedure. For these reasons, its use should be considered an integral part of the modern subperiosteal implant workflow.

Important

The only area not addressed by the cutting guide is the posterior maxilla when only a thin bone layer is present beneath the sinus floor. In all clinical situations, except for cases of extreme atrophy, a bone reduction guide is provided and should be used to prepare the bone and position the implant within the alveolar crest.

8.4 Incision Design in the Maxilla

In the maxilla, the incision design is a critical determinant of soft tissue outcomes. The most common error in maxillary subperiosteal surgery is making the incision in the mucosa, which displaces the entire keratinised gingival band toward the palate after closure. The result is an absence of attached,

keratinised gingiva on the vestibular side of the prosthetic abutments — the primary risk factor for progressive recession.

The HUG® Concept mandates a palatal shift of the incision. By placing the incision further toward the palate, the band of keratinised gingiva is translated vestibularly after reflection and repositioning. This ensures that, when the flap is closed, keratinised tissue is present on the vestibular aspect of each prosthetic abutment — providing the stable gingival seal that prevents recession.

Clinical Note

In the maxilla: always shift the incision palatally. This single step translates the keratinised gingival band to the vestibular side of the abutments and is the most important incision decision in maxillary subperiosteal surgery. A mucosally placed incision leads to no attached gingiva on the vestibular side — and a high rate of recession.

8.5 Incision Design in the Mandible

The mandible does not permit palatal incision shifting — there is no equivalent keratinised band on the lingual side that can be translated vestibularly. Managing soft tissues in the mandible therefore relies more heavily on the biomaterial strategy of Pillar 6 and the soft tissue augmentation described in that chapter.

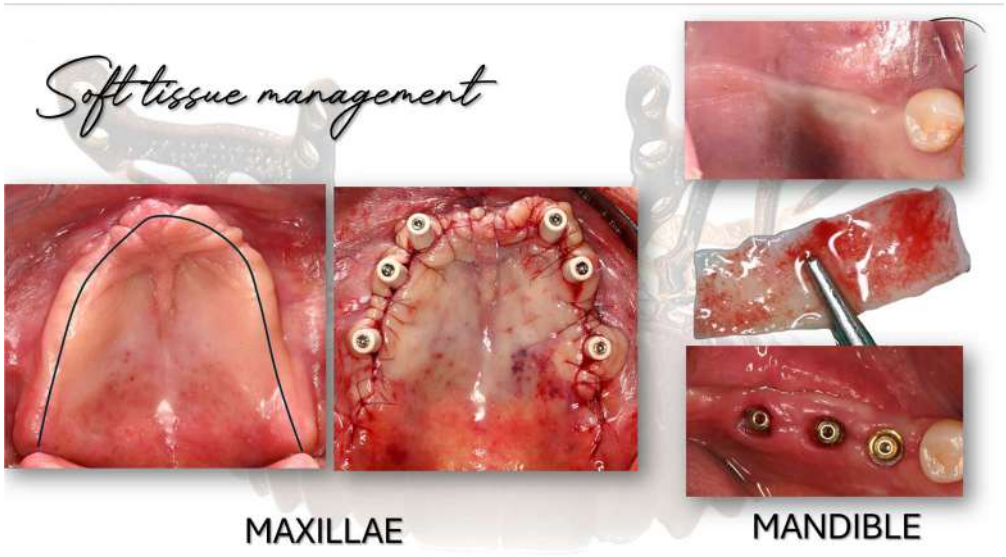


Figure 8.4 — Soft tissue management around digital subperiosteal implants. In the maxilla, a palatally positioned incision allows the band of keratinized tissue to be displaced toward the buccal aspect of the prosthetic. In the mandible, where this approach is not feasible, a connective tissue graft harvested from the palate is used to increase soft tissue thickness around the transmucosal components.

8.6 No Extraction and Immediate Implant Placement: Why?

Another important surgical principle is to avoid immediate extraction and implant placement whenever possible, even though successful cases can occasionally be achieved. Performing the

procedure at the time of extraction presents two main disadvantages. First, depending on the patient's periodontal biotype, the amount of keratinized tissue on the buccal aspect of the future transmucosal pillars may be insufficient. In thin biotypes, little or no attached gingiva may remain, increasing the risk of soft tissue recession. Second, immediate placement prevents the surgeon from shifting the incision palatally, which is a key strategy for improving the quality and quantity of buccal keratinized tissue. By delaying implant placement for approximately two months after extraction, a significant amount of attached gingiva can often be gained without any additional soft tissue procedure. This tissue can then be repositioned to the buccal aspect through palatal incision shifting, thereby improving long-term soft tissue stability around the prosthetic pillars.

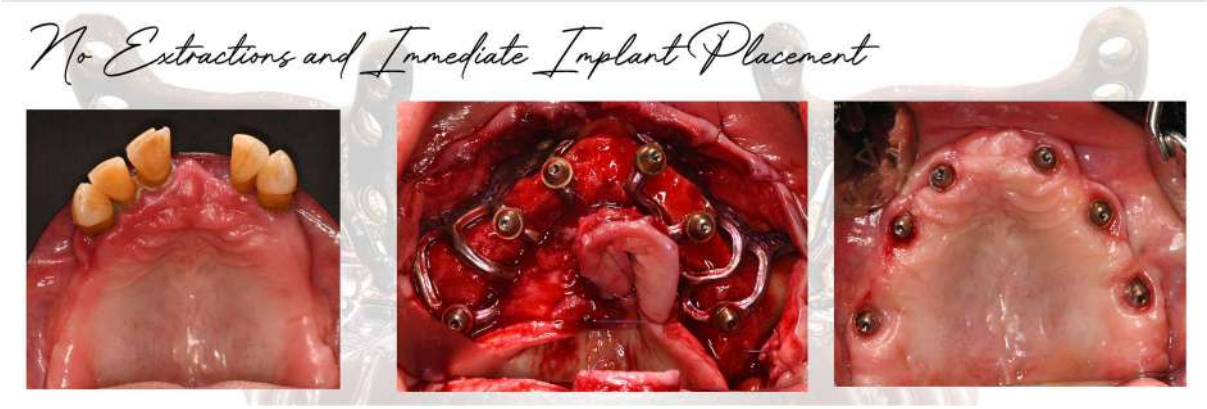


Figure 8.5 — Immediate extraction and placement of a maxillary subperiosteal implant. Although feasible in selected cases, this approach may compromise soft tissue management by reducing the amount of buccal attached gingiva and preventing palatal incision shifting, potentially increasing the risk of soft tissue recession around the pillars.

Another important advantage, which will be discussed later in this book, is that delayed placement allows the workflow to be performed on completely healed ridges. This avoids the presence of metallic artifacts originating from failed implants, root posts, or retained metallic restorations that may interfere with CBCT imaging. Reducing these artifacts improves the accuracy of segmentation, facilitates a more precise anatomical reconstruction, and ultimately enhances the fit of the custom implant as well as the overall accuracy of the digital workflow.

References

Den Borre CV, De Neef B, Loomans NAJ, et al. Soft Tissue Response and Determination of Underlying Risk Drivers for Recession and Mucositis after AMSJI Implantation in the Maxilla. Int J Oral Maxillofac Implants. 2024;39(2):302–309.

Van den Borre C, Otero JJ, Loomans N, et al. Retrospective analyses of additively manufactured subperiosteal jaw implants in the mandible. J Cranio-Maxillofac Surg. 2025.

Vaira LA, Biglio A, Favro A, Salzano G, Abbate V, Lechien JR, De Riu G. Implant-prosthetic rehabilitation of the atrophic posterior mandible with additively manufactured custom-made subperiosteal implants: a cohort study. Int J Oral Maxillofac Surg. 2024 Jun;53(6):533–540.

Chapter 9 — Pillar 6 — Tissue Management

Tissue management is arguably the most critical — and most frequently underestimated — pillar of the HUG® Concept. It encompasses both hard tissue management (bone regeneration above the implant) and soft tissue management (creating stable, thick keratinised gingiva around the abutments). Neither can be neglected without compromising the biological integration and aesthetic outcome of the rehabilitation.

9.1 The Goal: An Intraosseous Subperiosteal Implant

The overarching objective of tissue management is to achieve what we call an intraosseous subperiosteal implant — a device that, despite its design as a subperiosteal structure resting on the bone surface, ends up covered by regenerated bone above. This transforms the implant from a surface-level plate into a partially buried device, dramatically improving the stability of the overlying soft tissues and reducing the risk of recession.

This goal is achievable but not automatic. It requires the right biomaterial, the right membrane, and the right volume — applied correctly at the time of surgery.

9.2 Evidence: The Lattice Alone Is Not Enough

A 2022 study by Bai and colleagues placed 3D-printed titanium lattice subperiosteal implants without biomaterial coverage in the mandibles of dogs, with a 12-month follow-up. The implants were fully submerged under mucosa, with no oral communication. Micro-CT and histological analysis showed clear new bone formation inside the lattice and around the fixation screws — confirming the osseointegration potential of the lattice structure.

However, the same sections also revealed fibrous connective tissue in portions of the framework. The implant alone was not sufficient to achieve complete osseointegration of all surfaces. The periosteum, left without biological guidance, allowed fibrous tissue to colonise areas where bone formation had not yet occurred.

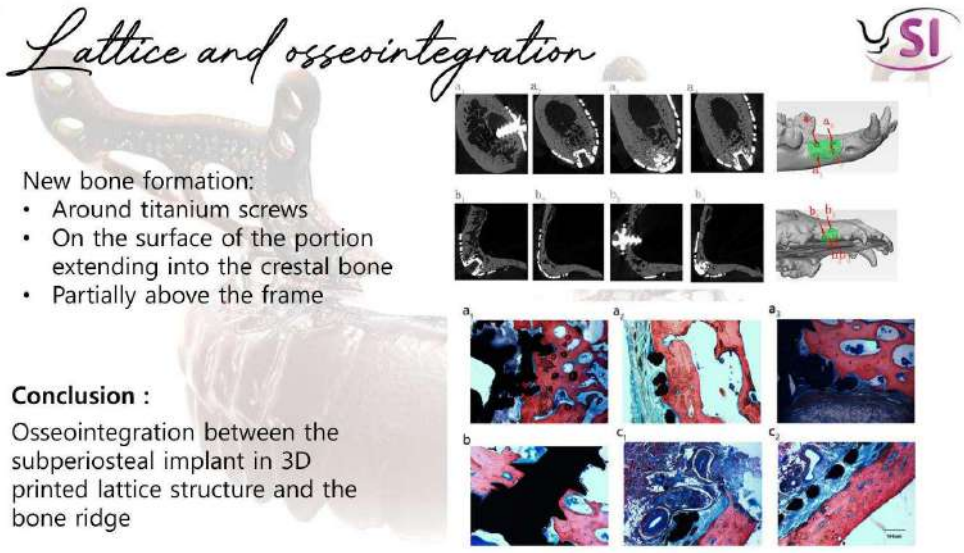


Figure 9.1 — Micro-CT and histological cross-sections: new bone formation around titanium screws (a1–a4), on the crestal surface of the implant (b1–b4), and the mixed bone/fibrous tissue interface above the implant framework (c1, c2). Adapted from Bai et al. (ACS Biomater Sci Eng, 2022)

9.3 Biomaterial Coverage: The Evidence

Two key studies inform the biomaterial protocol of the HUG® Concept. Aaboe and colleagues (2000) placed titanium subperiosteal implants around rabbit tibiae and filled the space above the implant with bovine bone substitute, covered by three different membrane types: collagen, polyglactin, and ePTFE. Bone formation above the implant was observed in all three membrane groups. Critically, no bone formation occurred in control implants placed without biomaterial.

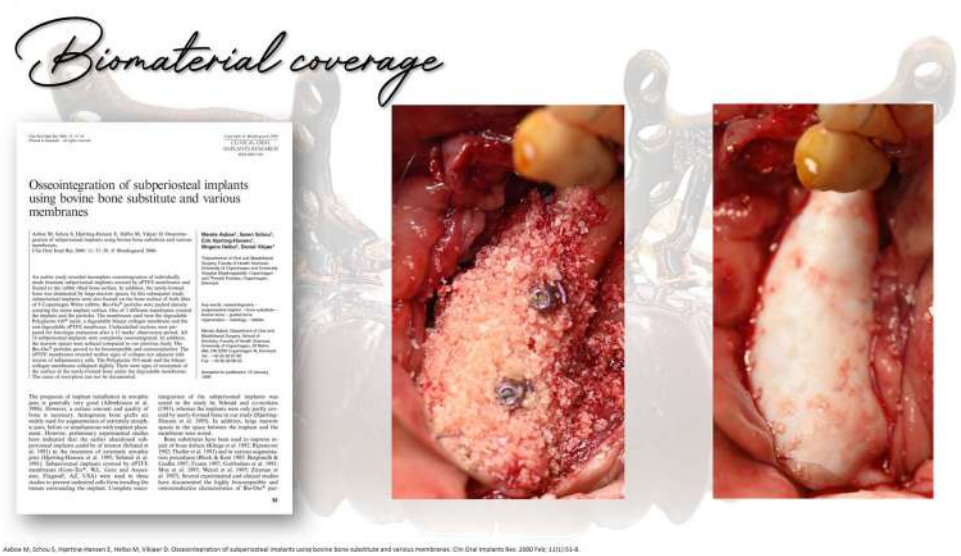


Figure 9.2 — Biomaterial coverage of a subperiosteal implant. Following implant placement, the exposed framework is covered with particulate bone graft and a resorbable collagen membrane. Experimental studies have demonstrated that this approach promotes bone formation over the implant surface and limits fibrous tissue proliferation, thereby enhancing biological integration and long-term tissue stability. Adapted from Aboe et al., 2000.

A second key study by Cohen and colleagues (2016) placed 3D-printed titanium discs with holes under the periosteum of rat skulls, with and without a thin layer of demineralised bone matrix (DBX). Bone ingrowth and pull-out strength were significantly higher when DBX was used — even without a membrane. The biomaterial acts as a periosteal spacer, creating and maintaining the anatomical space in which bone can form.

Figure 9.3 — Bone ingrowth and pull-out strength significantly higher with DBX coverage. Rough + DBX group shows markedly superior bone volume (BV/TV%) at 5 and 10 weeks, and highest pull-out force at week 10. The biomaterial acts as both biological stimulant and spatial maintainer. Adapted from Cohen and al. 2016.

9.4 The HUG® Biomaterial Protocol

Based on this evidence, the HUG® Concept uses a xenograft combined with a resorbable collagen membrane to cover the implant body. For a full-arch case, the standard volume is 1.5 to 2 grams of xenograft on each side — sufficient to create a stable, spacer-maintained regeneration chamber above the entire implant body. The HUG® implants are completely covered with xenograft before the membrane is applied and the flap is closed.

Earlier protocols used Collapat II (a collagen sponge containing bovine hydroxyapatite) soaked with PRF. This was chosen for its atraumatic profile — important in the context of potential mucosal healing delays. Good clinical results were obtained, but CBCT evaluation at four months did not confirm bone formation above the implant structure, likely because Collapat II does not act as an effective periosteal spacer. The current protocol with granular xenograft provides better space maintenance and more predictable bone regeneration.

Today, we prefer to use a combination of porcine and bovine xenografts to take advantage of the complementary biological properties of both materials. Porcine bone retains its native collagen matrix, which promotes cellular colonization and faster remodeling into newly formed vital bone. In contrast, deproteinized bovine mineral lacks collagen and is resorbed much more slowly, providing excellent long-term volume stability. By combining these two xenografts, the graft benefits from both

accelerated bone regeneration and prolonged maintenance of the regenerated volume, thereby offering a favorable biological environment for implant integration and long-term tissue stability.

Figure 9.4 — Collapat II® + PRF: early bone filling protocol (now superseded). Used initially for its safety profile, but CBCT at 4 months showed insufficient bone formation above the implant. Current protocol uses granular xenograft + resorbable membrane.

9.5 Unilateral Posterior Case: A Two-Stage Surgical Protocol

In posterior mandibular and maxillary rehabilitations, we preferentially use a two-stage surgical protocol whenever the clinical situation allows it. After placement and fixation of the implant, the entire framework is covered with particulate bone graft and a collagen membrane before complete flap closure. No healing abutments are connected during this first stage, allowing the surgical site to heal in a completely submerged environment.

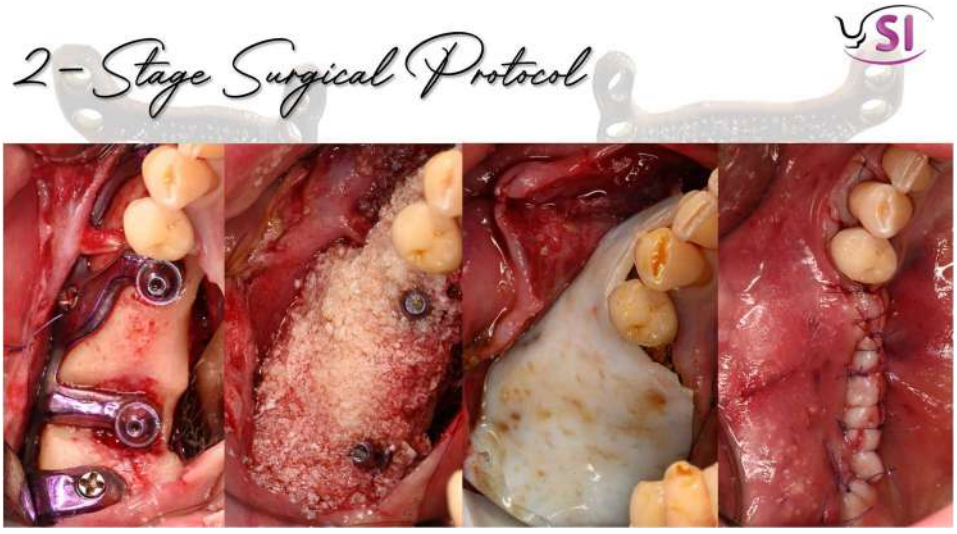


Figure 9.5 — Current xenograft coverage protocol: sequence showing implant in position, xenograft applied over the entire implant body, collagen membrane placed over xenograft. The implant is fully buried under regenerative material before flap closure.

This approach offers several biological advantages. First, it protects the grafted area from the oral environment and minimizes the risk of bacterial contamination during the early healing phase. Second, the implant abutments act as tenting poles that support the membrane and maintain a protected regenerative space above the implant arms. This space maintenance effect promotes bone formation and allows a greater volume of regenerated bone to develop over the framework.

One of the primary objectives of this protocol is to maximize bone regeneration above the implant body and arms. By avoiding early transmucosal exposure, the graft remains protected and can mature under optimal conditions. At the time of the second-stage surgery, usually performed after four months of healing, a substantial amount of newly formed tissue can often be observed covering the implant structure.

Figure 9.6 — Two-stage surgical protocol for posterior mandibular rehabilitation. Clinical sequence showing the initial soft tissue situation, spontaneous healing after four months of submerged healing, exposure of the transmucosal abutments during the second-stage surgery, placement of healing caps, and delivery of the provisional restoration two weeks later.

During this second stage, the abutments are exposed and healing caps are connected. The soft tissue response is generally excellent, and after a short maturation period, provisional and subsequently definitive restorations can be delivered. In our experience, this two-stage approach provides superior tissue integration, improved bone coverage of the implant framework, and highly predictable long-term outcomes in posterior mandibular cases.

CBCT examinations performed during healing frequently demonstrate progressive densification of the tissues located above the implant body, reflecting ongoing mineralization and maturation of the regenerated compartment. While radiological observations alone cannot confirm the exact histological nature of the tissue, the progressive increase in radiographic density observed over time is consistent with the biological concept of an intraosseous-subperiosteal implant. In this model, the implant framework becomes progressively incorporated into newly formed bone rather than remaining surrounded exclusively by fibrous connective tissue, potentially improving long-term biological integration and tissue stability.

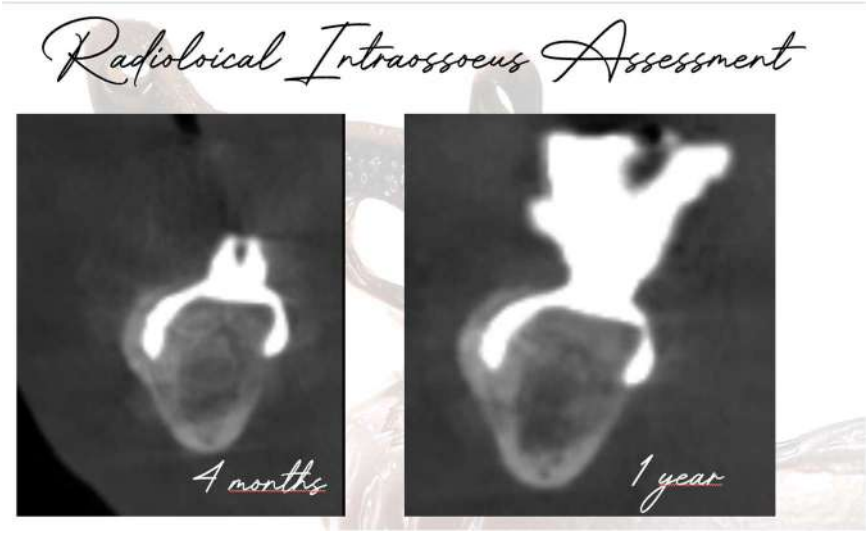


Figure 9.7 — Radiological assessment of intraosseous integration over time. Cross-sectional CBCT images obtained at 4 months and 1 year following implant placement. Progressive radiographic densification can be observed above the implant framework, suggesting ongoing bone formation and maturation within the regenerated compartment. These findings are consistent with the concept of an intraosseous-subperiosteal implant, where the external surface of the framework becomes progressively incorporated into newly formed bone over time.

In the maxilla, and in situations where immediate loading is required—particularly for aesthetic reasons or in full-arch rehabilitations—the protocol differs slightly. Bone grafting and membrane coverage remain mandatory to promote bone formation over the implant body. However, because the transmucosal abutments must remain exposed to support the provisional restoration, the "tenting effect" created by buried abutments is partially lost. As a result, although bone regeneration still occurs above the implant framework, the volume of newly formed bone is generally less substantial than that observed with a fully submerged two-stage protocol. Nevertheless, this approach represents an acceptable compromise when immediate function or aesthetics are required, while still preserving the biological benefits of biomaterial coverage.

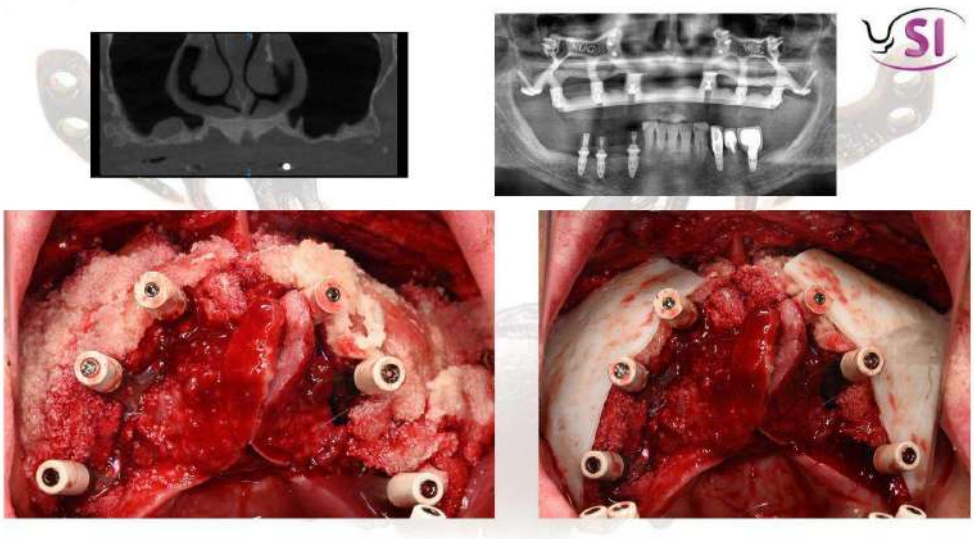


Figure 9.8 — Intraoperative photographs of the complete tissue management protocol in a maxillary full-arch case. Left: CBCT cross-section confirming severe atrophy. Right: panoramic radiograph at 4 months showing implant integration. Operative photographs: xenograft applied bilaterally (lower left), GBR membrane coverage (lower right).

9.6 Clinical Application of GBR Membranes

In immediate loading cases, particularly in the maxilla and in full-arch rehabilitations, we now systematically use resorbable collagen GBR membranes. These membranes are perforated around the implant abutments and positioned over the grafted area before flap closure.

Their role is particularly important because periosteal-releasing incisions are required to advance the buccal flaps and obtain tension-free closure. Therefore, the grafted biomaterial is no longer covered exclusively by periosteum but may come into contact with muscle and connective tissues. Under these conditions, the osteogenic potential of the periosteum is largely lost.

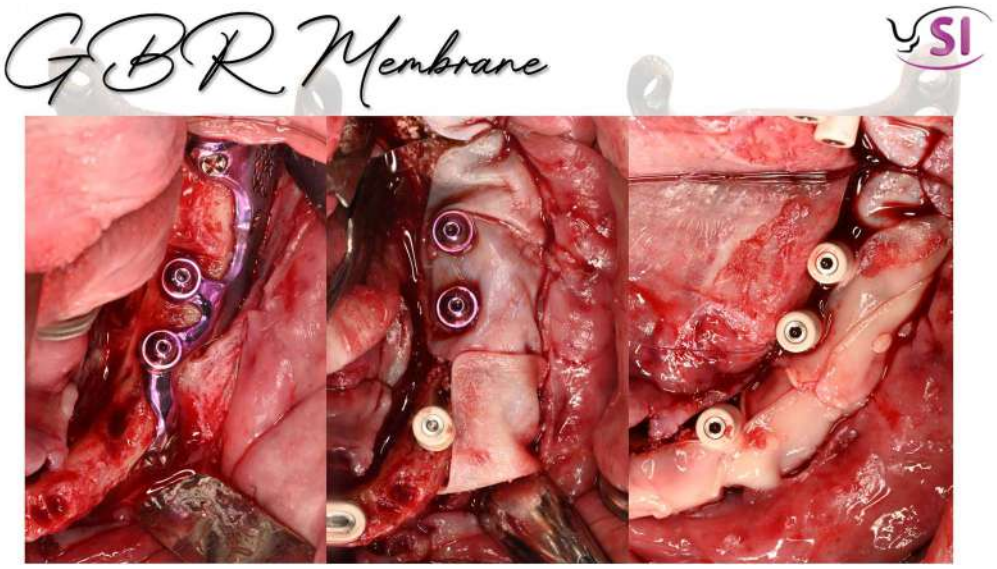


Figure 9.9 — Mandibular application of GBR principles around a subperiosteal implant. Following bone graft placement, a resorbable collagen membrane is adapted around the transmucosal abutments to exclude soft tissue cells and protect the regenerative space. The membrane is subsequently covered with PRF membranes, providing early biological sealing and supporting soft tissue healing during the initial phases of regeneration.

According to the principles of Guided Bone Regeneration (GBR), it is essential to provide sufficient time for osteogenic and bone-forming cells to colonize the grafted area while excluding soft tissue and muscle cells, which possess a much faster healing and proliferative capacity. The collagen membrane therefore acts as a selective barrier, protecting the regenerative space and promoting predictable bone formation over the implant framework.

To further enhance soft tissue healing, the collagen membrane is covered with PRF membranes. While the collagen membrane provides cell exclusion and space maintenance, the PRF membranes contribute to early biological sealing of the surgical site and support the initial phases of wound healing beneath the flap.

9.7 Soft Tissue Management: Use of an Acellular Dermal Matrix

Bone regeneration above the implant addresses the hard tissue component of tissue management. Thin gingival tissue on the vestibular side of the prosthetic abutments provides inadequate protection against recession, bacterial penetration, and progressive exposure of the implant framework. This issue is particularly important in the mandible, where it is not possible to shift the incision palatally, as can be done in the maxilla.

To increase the thickness of the vestibular soft tissues, the first option is the use of connective tissue grafts harvested from the palate. Although this technique is effective, it increases both the duration of the surgery and patient morbidity due to the creation of a second surgical site.

Another solution used in the HUG® Concept is the use of a cell-free dermal matrix derived from porcine dermis. We use NovoMatrix® as an alternative to autogenous connective tissue grafts. NovoMatrix is tear-resistant, easy to handle, and provides a consistent 1 mm gain in connective tissue thickness. Its LifeCell™ processing allows rapid revascularisation, and its consistent fabric thickness makes it easier to work with than autologous connective tissue grafts, which can vary in quality and thickness.

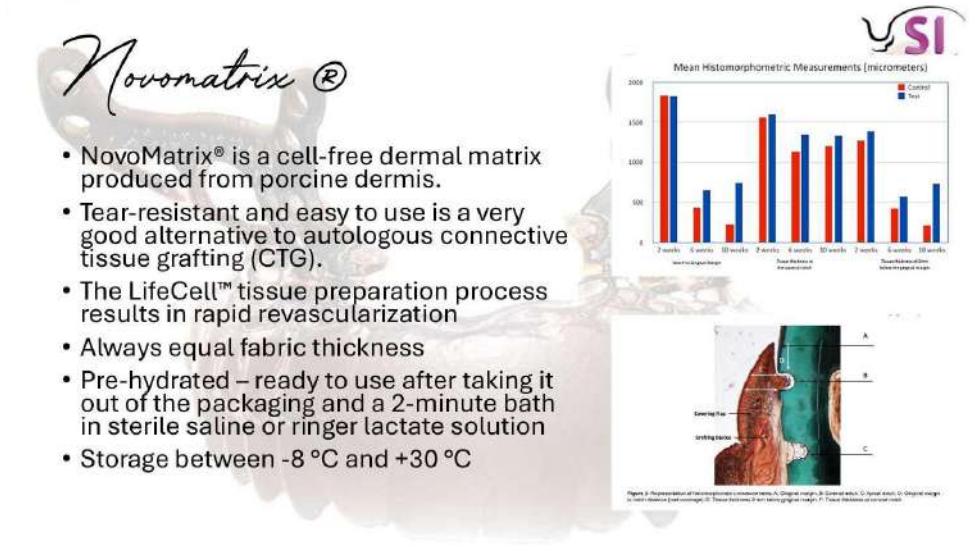


Figure 9.10 — NovoMatrix® properties and histomorphometric data: consistent tissue thickness gain over 2–10 weeks (bar graphs). Cross-section illustration showing the position of NovoMatrix as a grafting device beneath the covering flap, with the gingival margin (A), coronal notch (B), and apical notch (C) reference points.

NovoMatrix® is currently used systematically in mandibular cases treated with a two-stage approach. In immediate loading cases in the mandible, however, a GBR membrane is preferred. If NovoMatrix® is not completely buried beneath the flap and remains exposed to saliva and oral bacteria, there is a risk of postoperative infection because its resorption time is considerably longer than that of an exposed GBR membrane.

In the maxilla, the palatal incision shift, which translates keratinized gingiva to the vestibular side, significantly reduces the need for soft tissue augmentation procedures.

Clinical Note

Important: always soak NovoMatrix for at least two minutes in physiological saline before use. If you are a PRF user, liquid plasma is an excellent alternative soaking medium. Some clinicians have reported inflammatory reactions with dry placement — this step is mandatory, not optional.

9.8 Protocol Summary

The tissue management protocol differs between maxilla and mandible, and the differences reflect the anatomical constraints of each site.

Step	Maxilla	Mandible
Incision	Palatal shift — translates keratinised band to vestibular	Standard — no shift possible
Hard tissue	2 g xenograft each side + GBR membrane	Full arch: 1.5g xenograft + GBR membrane Partial case: 1.5g xenograft + Dermal Matrix
Soft tissue	Palatal shift usually sufficient;	Full-arch: Connective tissue graft or abstention Partial case: Dermal Matrix®
Staging	Full-arch: one-stage Partial case: two-stage	Full-arch: one-stage Partial case: two-stage
Final advice	Do not create tension during flap closure.	Do not create tension during flap closure.

Table 9.1 — Tissue management protocol summary for maxillary and mandibular HUG® cases.

In cases of large oro-antral communication, the use of a buccal fat pad graft may be preferred, avoiding the placement of biomaterials. When delayed wound healing is anticipated, Collapat II remains a valuable alternative due to its atraumatic healing profile.

Successful tissue management in subperiosteal implantology is not governed by a single technique — it is the result of an integrated clinical reasoning process that weighs patient factors, anatomical context, biological objectives, and surgical strategy simultaneously. The decision-making framework illustrated in Figure 9.11 organises these elements into three interacting domains.

Patient and anatomical considerations form the first domain and must be evaluated before any surgical decision is made. Many patients referred for subperiosteal implants have a history of previous implant failures, systemic or local pathologies, or an elevated inflammatory index — all of which directly increase the risk of post-operative complications. The anatomical site is equally determinant: the mandible and maxilla differ profoundly in bone density, cortical thickness, vascular supply, and soft tissue behaviour. These differences require distinct surgical approaches and distinct biomaterial strategies, and they cannot be ignored in treatment planning.

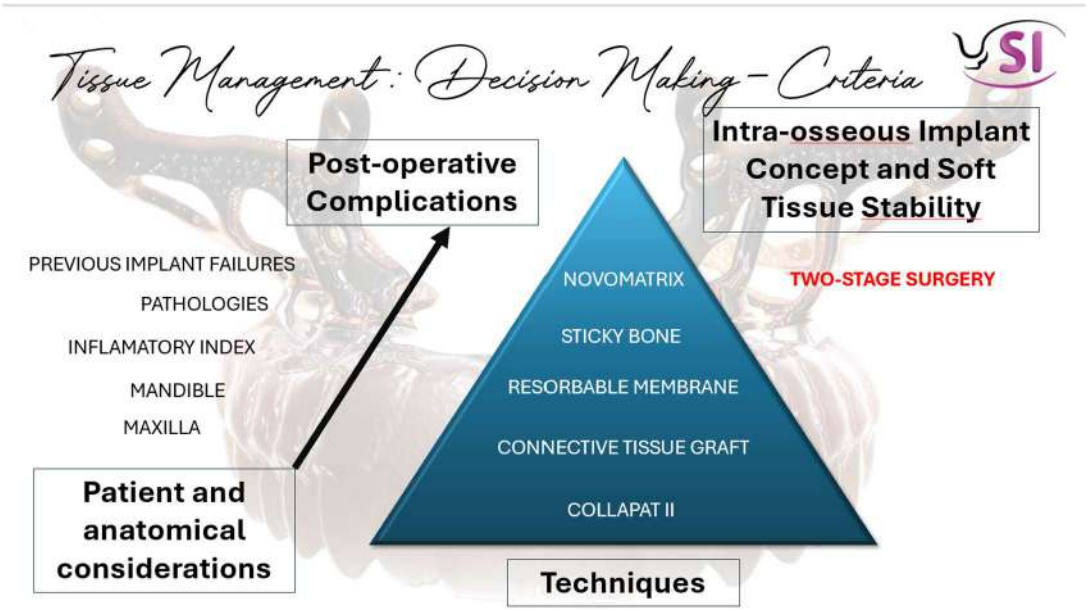


Figure 9.11 — Decision-making framework for tissue management in subperiosteal implantology. The central pyramid represents the available surgical and biomaterial techniques, ranked from the least invasive (bottom) to the most advanced (apex). As one moves toward the apex, these approaches are more likely to promote the intraosseous concept but are also associated with a higher risk of complications. On the left are the patient-related and anatomical risk factors that should be evaluated preoperatively.

The risk of post-operative complications — represented at the apex of the diagram — is the direct consequence of ignoring or underestimating these patient and anatomical factors. Soft tissue exposure, persistent infection, and peri-implant recession do not occur randomly; they occur when the clinical context exceeds the biological tolerance of the chosen technique. The goal of the decision-making process is to anticipate and mitigate this risk before it materialises.

The intraosseous implant concept is the biological objective that orients all technical choices: to achieve bone formation above and around the implant arms, creating a vascularised foundation for the overlying soft tissue. Every technique in the central pyramid serves this objective. Sticky bone provides the osteoinductive environment; a resorbable membrane maintains the regenerative space; two-stage surgery allows bone consolidation before prosthetic loading; connective tissue grafting our Novomatrix ® reinforces the soft tissue envelope where keratinised tissue is insufficient; and Collapat II® provides a resorbable collagen scaffold adapted to each anatomical situation.

The key message of this framework is that no single technique is universally indicated. The choice of biomaterials and surgical approach must be tailored to the specific combination of risk factors, anatomical constraints, and biological objectives present in each case. A patient with previous implant failures, a thin biotype, and mandibular placement requires a very different tissue management strategy than a healthy patient undergoing maxillary rehabilitation with adequate keratinised tissue. The higher one moves toward the apex of the pyramid, the more the selected techniques contribute to achieving the intraosseous subperiosteal concept. However, these techniques are also associated with an increased risk of postoperative complications. Therefore, the choice of surgical and biomaterial strategies must be carefully balanced against patient-related factors and the specific anatomical conditions of each clinical situation.

But finally, the Two-stage surgery represents one of the most effective approaches for achieving the intraosseous concept while simultaneously reducing the risk of complications. For this reason, we strive to implement this technique whenever possible, although we fully acknowledge that it departs from the original philosophy of subperiosteal implants, which consisted of placing a metallic framework in a single surgical procedure followed by immediate loading. Nevertheless, if this approach results in more predictable and durable long-term outcomes, it should be favored.

9.9 The Biological Space: Maintaining Bone Over Time

Creating new bone above the implant arm is a significant achievement — but maintaining it over time is even more important. Bone that is regenerated under ideal conditions can be lost if it is chronically irritated. In the context of subperiosteal implants, the connection between the prosthetic abutment and the prosthesis represents a potential source of chronic irritation, because it is not a sealed connection. Unlike the conical implant–abutment connection found in modern endosseous implants, which creates a tight biological seal, the MUA connection of subperiosteal implants is inherently exposed to bacterial ingress and microflexion under load.

If our goal is to maintain at least one millimeter of bone above the implant arm — which provides the vascularized foundation necessary to prevent soft tissue recession — then the MUA–prosthesis interface must be positioned at a sufficient distance from this regenerated bone. Based on clinical reasoning and the biological space concept adapted from endo-osseous implantology, this distance should be at least two millimeters. This means a minimum multi-unit abutment height of three millimeters: one millimeter of bone above the arm, plus two millimeters of biological space to the abutment–prosthesis junction.

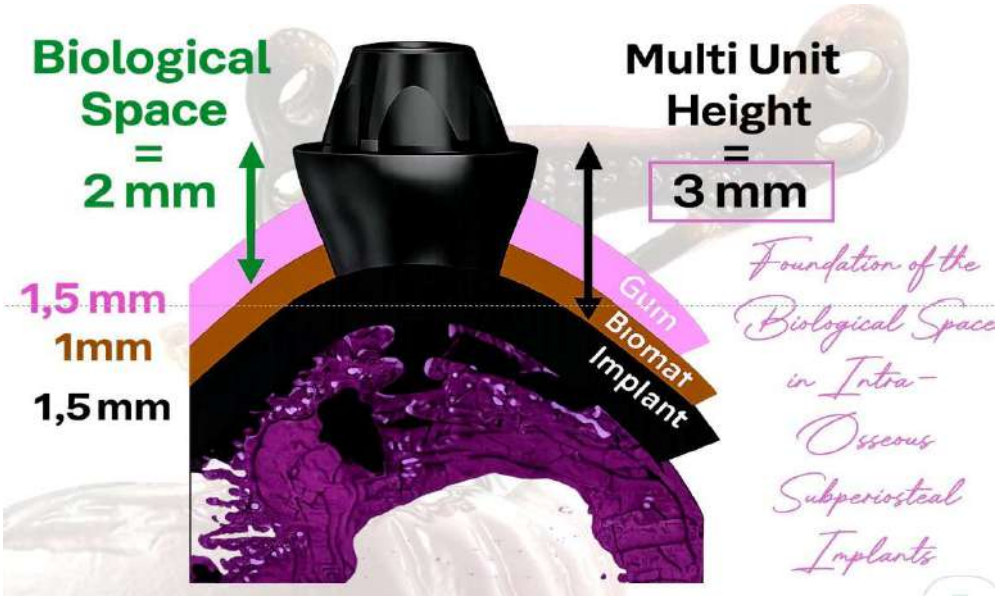


Figure 9.12 — The biological space in intraosseous subperiosteal implants. A minimum multi-unit abutment height of 3 mm is required: 1 mm of biomaterial/bone coverage + 2 mm of distance from the prosthetic connection = a total distance of 3 mm. This distance protects the regenerated bone from chronic irritation and is the foundation of long-term bone maintenance around subperiosteal implant abutments.

This minimum distance — three millimeters of MUA height — is what we consider the foundation of the biological space in intraosseous subperiosteal implants. Without it, even perfectly regenerated bone will be exposed to the inflammatory consequences of the abutment–prosthesis

microenvironment and is likely to resorb over time. With it, the regenerated bone is protected, and the long-term soft tissue stability described throughout this chapter becomes achievable and maintainable.

9.10 Monobloc or Removable Multi-Unit Abutment ?

This concept also explains why we do not currently recommend removable multi-unit abutments with different heights.

Some companies propose removable abutments as a solution in the event of screw fracture, since the abutment can theoretically be replaced without removing the entire implant structure. Although this approach may offer prosthetic advantages, we do not recommend it at present.

These connections are generally flat and lack a sealed interface. As a result, they may disrupt the biological space around the implant and compromise our ability to maintain bone above the implant arm. Preserving this suprastructural bone is one of the key objectives of the intraosseous subperiosteal concept. For this reason, we currently prefer a monobloc abutment integrated into the implant structure.

Another reason concerns the prevention of peri-implantitis. During healing, the soft tissues tend to contract slightly, and small spaces naturally develop beneath the prosthesis. These spaces should not be closed, as they provide access for oral hygiene and facilitate long-term maintenance under the bridge.

This is another reason why we do not recommend removable multi-unit abutments with different heights. Their use may encourage the clinician to close these spaces prosthetically, potentially compromising hygiene access and the long-term stability of the peri-implant tissues. This concept will be discussed further in the prosthetic chapter, particularly in relation to the bridge-on-stilts concept.

References

Bai L, Zheng L, Ji P, Wan H, Zhou N, Liu R, Wang C. Additively Manufactured Lattice-like Subperiosteal Implants for Rehabilitation of the Severely Atrophic Ridge. ACS Biomater Sci Eng. 2022 Feb 14;8(2):912–920.

Aaboe M, Schou S, Hjørting-Hansen E, Helbo M, Vikjaer D. Osseointegration of subperiosteal implants using bovine bone substitute and various membranes. Clin Oral Implants Res. 2000 Feb;11(1):51–8.

Cohen DJ, Cheng A, Kahn A, et al. Novel Osteogenic Ti-6Al-4V Device For Restoration Of Dental Function In Patients With Large Bone Deficiencies. Sci Rep. 2016;6:20493.

Vaira LA, Biglio A, Favro A, et al. Implant-prosthetic rehabilitation of the atrophic posterior mandible with additively manufactured custom-made subperiosteal implants. Int J Oral Maxillofac Surg. 2024;53(6):533–540.

Chapter 10 — Pillar 7 — Implant Replicas

Surgery without rehearsal is surgery without confidence. The HUG® implant replica system bridges the gap between digital planning and intraoperative reality — allowing the surgeon to physically interact with the planned implant geometry before the patient is on the table.

10.1 The Contamination Problem

The HUG® titanium implant is delivered decontaminated and sealed in a sterile bag, ready for sterilisation. The implant surface — anodised, clean, and biologically optimised — must not be contaminated or exposed to ambient air before placement. Even photography, which may seem innocuous, can compromise the surface if the implant is handled outside of sterile conditions.

This creates an immediate practical challenge: surgeons want to handle the implant before surgery, to understand its geometry, verify the fit on the model, test the guide, and plan the sequence of screw placement. How can they do this without contaminating the titanium device?

Figure 10.1 — The definitive titanium implant is delivered sealed and decontaminated and should not be handled before surgery to avoid contamination. PMMA replicas are included for manipulation, photography, and treatment planning.

10.2 The PMMA Replica Solution

The answer is the PMMA replica — a precise polymethylmethacrylate reproduction of the titanium implant, included in every HUG® package. The replica is not a simplified model; it is a geometrically accurate reproduction of the implant body, arms, and connection points. Every feature that the surgeon needs to understand — the lattice area, the wings, the fixation holes, the prosthetic arms — is present in the replica.

The replica allows the surgeon to rehearse every aspect of the implant placement procedure before opening the sterile titanium package. This includes: verifying that the replica seats correctly on the

resin jaw model; confirming that the fixation hole positions match the pre-drilled perforations in the model; testing the pterygoid guide trajectory with a drill; and planning the order and angulation of screw placement.

10.3 Using the Resin Jaw Model

The resin jaw model serves several functions beyond implant fitting. It is pre-drilled to match the planned screw positions, allowing the surgeon to rehearse the drilling sequence. After the bone cuts have been made with the cutting guide during surgery, the model provides a reference for verifying the bevelling and smoothing of bone edges. Having the model at the surgical field — not just on the planning workstation — allows real-time comparison between the planned and actual bone preparation. It should be used in conjunction with the planning report and the MedPrint® software, which also allow these verifications to be performed during the surgical procedure.

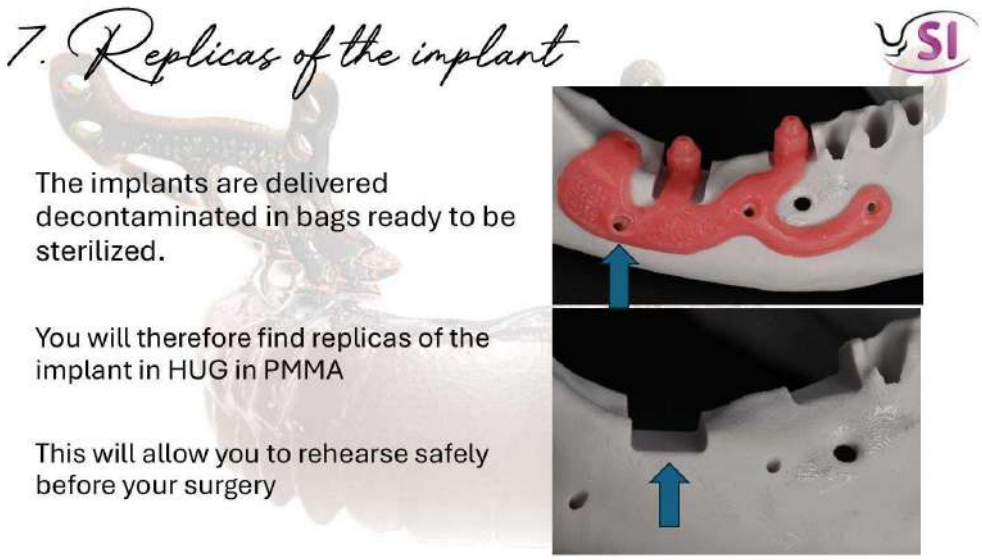


Figure 10.2 — The resin model allows intraoperative verification that the clinical situation accurately matches the preoperative planning. It should be kept readily available throughout the surgical procedure.

10.4 The Maxillary Pterygoid Rehearsal

For maxillary cases, the replica fulfils an additional specific function: testing the prosthetic guide for pterygoid anchorage. The surgeon inserts the drill through the guide tube on the replica and verifies where the tip exits at the pterygoid plate level on the model. If the exit point falls within the safe zone, that means, between the medial and lateral plate of the pterygoid and defined during digital planning, the surgeon can proceed with confidence. If it does not, the discrepancy is identified and resolved before surgery.

The safe zone for pterygoid anchor screws is relatively wide. The half-tube guide design provides sufficient directional control without requiring the extreme precision of a full-sleeve guide. The half-tube guide also provides valuable tactile feedback, allowing the surgeon to clearly feel the penetration of the pterygoid cortical bone. This tactile sensation helps determine precisely when the cortex has been engaged or traversed, enabling the surgeon to stop the advancement of the drill or screw at the appropriate moment. The rehearsal confirms — physically and tangibly — that the guidance system will deliver the screw to the intended location.

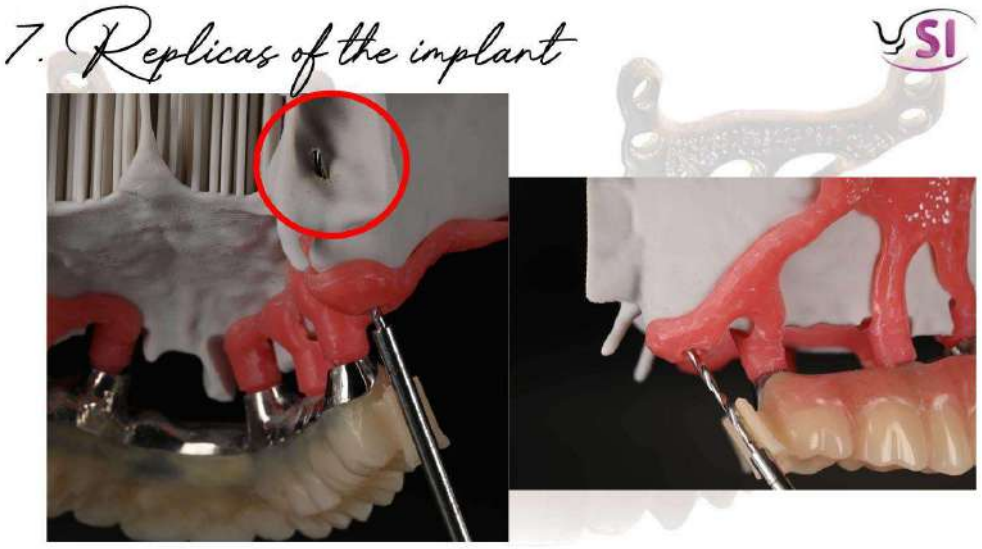


Figure 10.3 — Replica rehearsal: testing pterygoid guide drilling trajectory on the resin model (left). The exit point of the drill at the pterygoid plate is verified to lie within the safe zone. Right: replica seated on model with prosthetic bridge, confirming the complete assembly before surgery.

Clinical Note

Keep the resin jaw model at the surgical field throughout the procedure. It is your reference for bone edge bevelling, screw position verification, and implant seating confirmation. Do not put it away after rehearsal.

10.5 Two Additional Advantages of the Resin Replicas

Beyond surgical rehearsal and pterygoid guide verification, the PMMA replicas offer two additional practical advantages that directly improve the efficiency and safety of the procedure.

First, the collagen membrane punch can be prepared outside the mouth using the replica. Because the replica faithfully reproduces the geometry of the implant arms and connection points, the surgeon can precisely pre-cut the collagen membrane to the correct shape before the patient is in the surgical position. This reduces intraoperative time and ensures accurate membrane coverage from the first moment of placement.

Second, the replica allows the surgeon to verify that flap release is sufficient before opening the sterile titanium implant. After raising and releasing the flap, the PMMA replica can be seated into the surgical field to confirm that the soft tissue envelope allows correct implant positioning without excessive tension. This simple precaution avoids unnecessary manipulation of the sterile titanium device and protects both the implant surface and the patient's tissues.

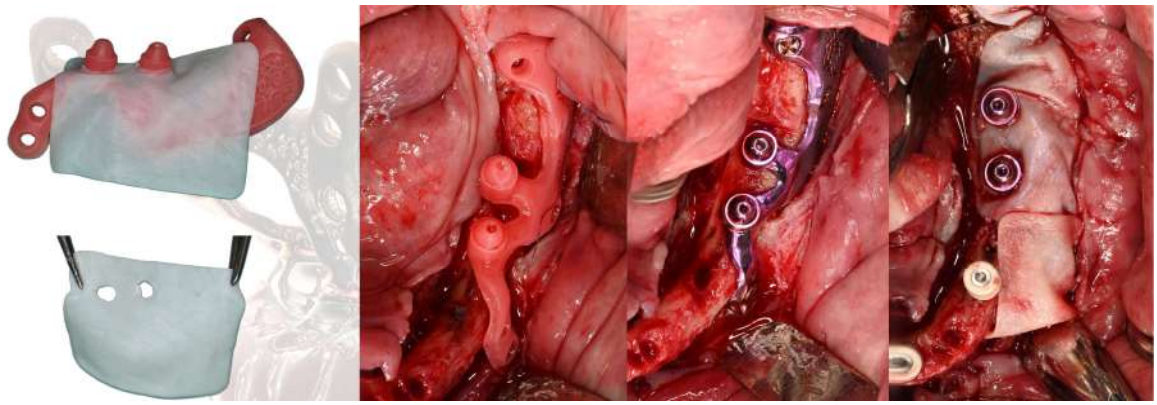


Figure 10.4 — Additional uses of the PMMA replica system. Left: replica used to pre-cut the collagen membrane outside the mouth. Right: intraoperative use of the replica to verify flap release and access before opening the sterile titanium implant packaging. This avoids unnecessary manipulation of the titanium device.

References

Diss A, Lerebours A, Grébenval C, Birault L. Pterygoid Anchorage of Subperiosteal Implants: An Overview and Case Report. Cureus. 2025 Jun 1;17(6):e85175.

Chapter 11 — Pillar 8 — The Prosthesis

The prosthesis is not an afterthought — it is an integral part of the HUG® Concept. A perfectly integrated implant can still fail if the prosthetic design compresses the regenerating tissues, overloads the connections, or prevents adequate patient hygiene. Pillar 8 defines the prosthetic philosophy that transforms a well-placed implant into a long-term clinical success.

11.1 Full-Arch Cases: The IBar Concept

One of the most distinctive features of the HUG® system is the delivery of a definitive prosthesis on the day of surgery. In full-arch edentulous cases, the patient enters the operating room without functional teeth and leaves with a permanent titanium-reinforced bridge. This is not a temporary provisional — it is the final restoration.

This is made possible by the precision of the digital workflow (Pillar 9). Because every component is designed, validated, and manufactured before surgery, the bridge fits passively on the abutments from the first moment of placement. The surgeon screws the bridge to the abutments intraoperatively, confirms fit and occlusion, and the patient is immediately rehabilitated.

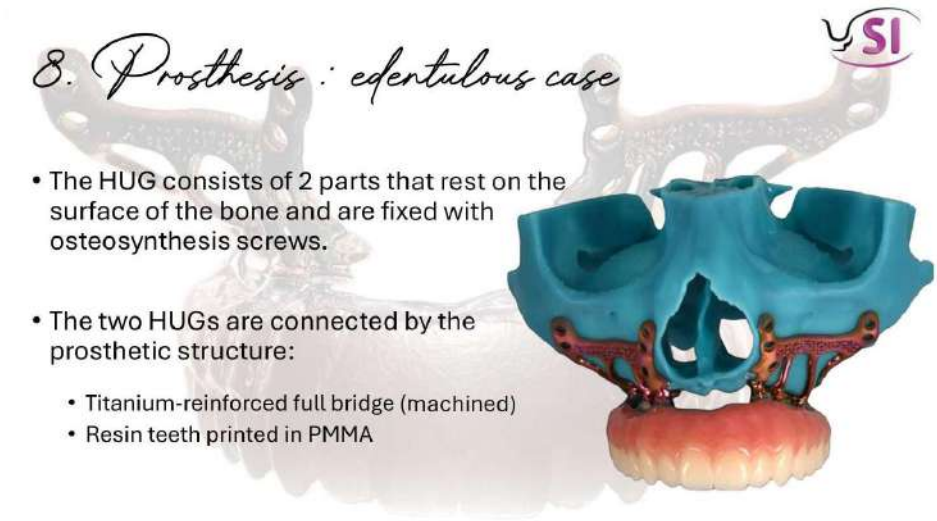


Figure 11.1 — Full-arch HUG® case: the system consists of two implants resting on the bone surface, fixed with osteosynthesis screws, and connected by the prosthetic bridge: titanium-reinforced machined framework with 3D-printed PMMA resin teeth. The prosthesis is the structural integrator of both implants.

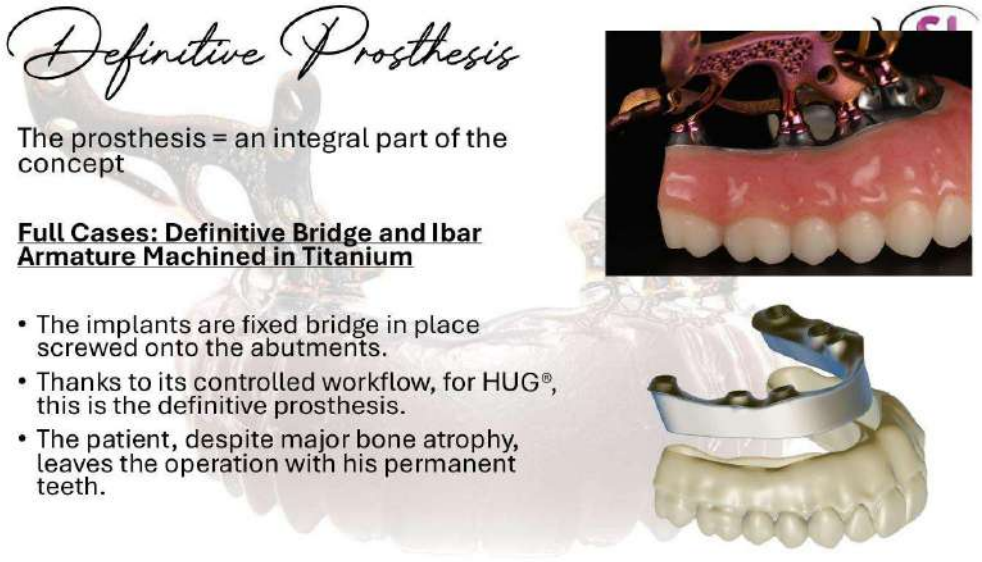


Figure 11.2 — Definitive prosthesis concept: titanium I-bar armature machined in titanium, with PMMA resin teeth. The bridge is screwed directly onto the MUA abutments at the time of surgery. For HUG®, this is the definitive prosthesis — not a temporary. The patient leaves surgery with permanent teeth.

This restoration should therefore be considered a definitive prosthesis consisting of a passively fitting milled titanium framework (Ibar) onto which resin or PMMA teeth are bonded. At present, we do not recommend full-zirconia full-arch prostheses, as they appear to be excessively rigid in relation to the implant structure.

Figure 11.3 — HUG® implant shells with I-bar prosthesis. The excellence of the passive fit between the bridge and the multi-unit abutments is clearly visible. The assembly is screw-retained and fully retrievable.

In the event of wear, fracture, or damage to the prosthetic teeth or esthetic components, it is possible to reprint new teeth and bond them directly onto the existing titanium framework. Consequently, the titanium framework itself is intended to remain in service throughout the lifetime of the implants.

Because its passive fit is established and validated during surgery, this framework provides an optimal fit to the implant structure, which may contribute to long-term mechanical stability.

11.2 Partial Cases: The Temporary PMMA Bridge

For partial cases, a full PMMA bridge serves as the temporary prosthetic connection. This bridge has two functions. First, it facilitates precise implant positioning by providing a physical reference structure during fixation: the bridge positions the implant relative to the remaining dentition and guides screw placement. Second, it improves grip during surgery, making the implant easier to handle and seat accurately.

After fixation, the bridge can either be left in place under occlusal contact or removed and reapplied four months later, when biological integration has been confirmed.

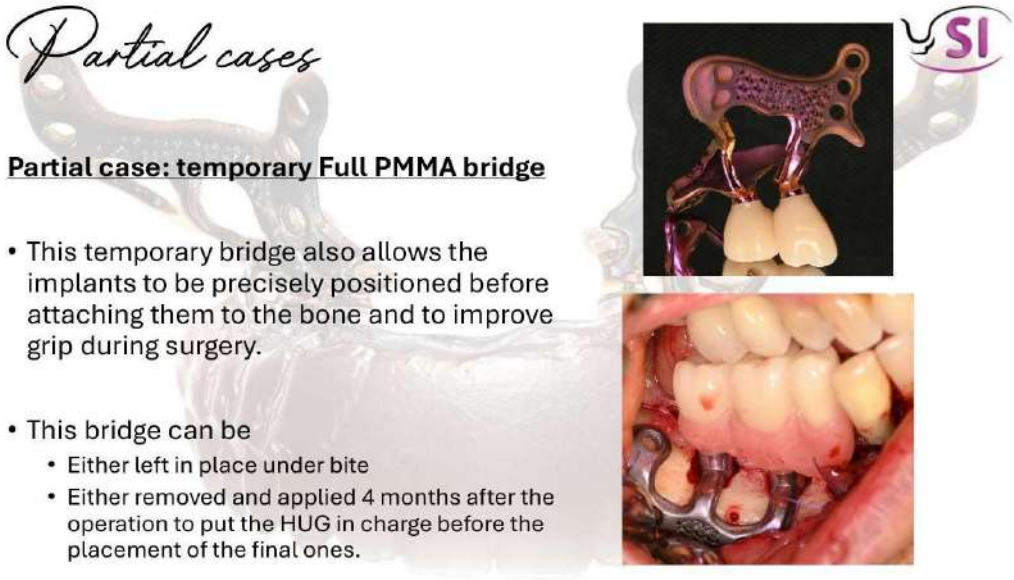


Figure 11.4 — Partial case protocol: temporary full PMMA bridge used during surgery as positioning guide and grip-improving device. Two options for loading: immediate (bridge left in place under bite) or delayed (bridge removed at surgery, reapplied at 4 months after confirmed osseointegration).

11.3 The Six-Pillar Connection Standard

For full-arch treatment, six prosthetic abutments represent the standard of care. This configuration provides optimal force distribution across the arch, reduces overloading on individual screws, and creates the mechanical redundancy necessary for long-term reliability. If one of the six abutments is compromised — by infection, recession, or fracture — the system can continue to function on five pillars while the problem is managed.

Systems using only four abutments require thicker prosthetic arms for mechanical compensation, which increases the risk of soft tissue compression and recession. More critically, a four-pillar system cannot be rescued if one abutment fails — the remaining three cannot adequately support full-arch function.

11.4 MUA Connection

The prosthetic connection uses a Biotech Dental MUA (Multi-Unit Abutment) standard. The MUA connection is well established in implant dentistry, with extensive literature on long-term reliability. The 4.9 mm platform width provides adequate space for screw access and restorative work. All HUG® prosthetic components — bridges, provisional crowns, abutment-level components — are designed around this connection standard.

11.5 Bridge Design: The "Bridge on Stilts" Philosophy

A fundamental principle of HUG® prosthetic design is to avoid soft tissue compression. Pressure on regenerating tissue under the bridge — whether from xenograft, dermal matrix, or healing gingiva — compromises the biological process and can cause necrosis, recession, or failure of the regeneration protocol.

In partial rehabilitations, we aim to avoid bulky prostheses with pink resin replacing the missing soft tissues. Instead, we favor cylindrical transmucosal emergence profiles that do not compress the regenerated tissues and allow adequate access for interdental brushes and oral hygiene procedures. We are also increasingly using definitive partial full-zirconia bridges without titanium bases, retained with dedicated prosthetic screws. This approach provides an optimal biological response of the surrounding soft tissues. In partial rehabilitations, the rigidity of the prosthesis appears to be less critical than in full-arch cases, making monolithic zirconia restorations a valuable alternative.

Figure 11.5 — Prosthetic design evolution: old design (left) — tissue over-compression risk with full tissue-contact bridge. New design (right) — scalloped, reduced vestibular convexity leaving space between the framework and soft tissues. The "bridge on stilts" concept prioritises hygiene access over aesthetics.

For full-arch cases, the HUG® design philosophy deliberately creates space between the bridge and the underlying soft tissues. We call this the "bridge on stilts" concept: the framework connects the prosthetic abutments high above the tissue level, leaving a visible gap that the patient can clean under with a brush or interdental device. Food stagnation, air leakage, or occasional saliva droplets are accepted tradeoffs for the ability to maintain hygiene and avoid tissue compression.

11.6 Peri-Implant Disease: A Warning from the All-on-Four Literature

The prevalence of peri-implant diseases in fixed full-arch implant-supported prostheses is higher than many clinicians assume — and the published data from the All-on-Four literature must serve as a sobering reference point when designing subperiosteal prostheses. A systematic literature review by Margvelashvili-Malament and Eckert (2022), based on studies published between 1995 and 2021, reported that peri-implant mucositis affected up to 30.2% of patients and up to 18.3% of implants; peri-implantitis affected up to 25% of patients and up to 7.2% of implants, over follow-up periods of five to ten years. Despite these rates, implant and prosthesis survival remained moderately high — but the authors emphasised that strict long-term maintenance was essential to mitigate biologic complications.

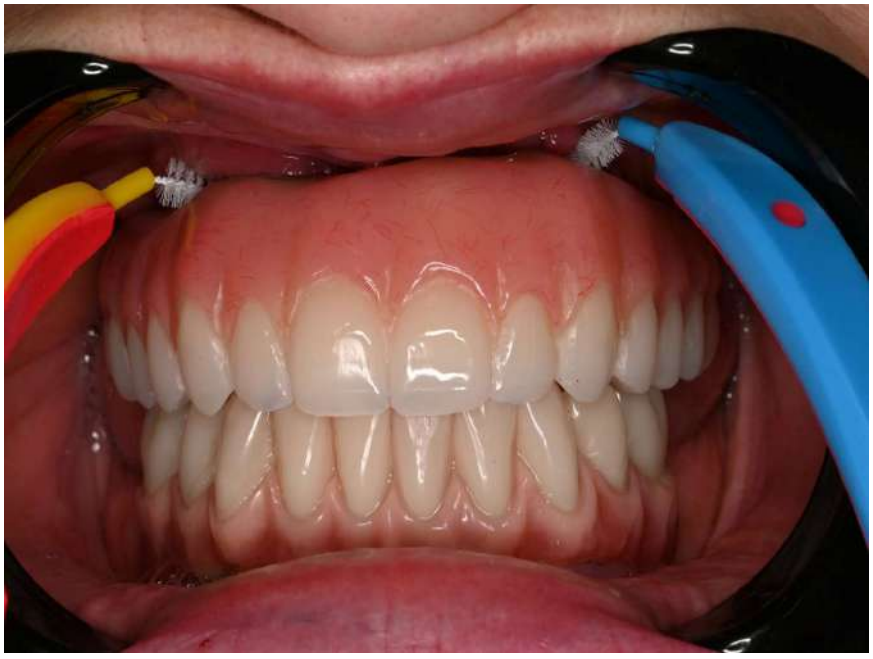


Figure 11.6 — Clinical photograph of the "bridge on stilts" design in function, showing the visible gap between the prosthetic framework and the underlying soft tissues. Interdental brushes can be passed freely beneath the bridge, enabling effective patient hygiene — the primary goal of this prosthetic design philosophy.

These figures carry a specific warning for subperiosteal implantology. In the All-on-Four context, peri-implantitis affects endosseous implants with a well-defined bony seal. In subperiosteal implants, the tissue–implant interface is more complex and the consequences of chronic inflammation potentially more severe. If peri-implant disease develops around a subperiosteal implant, we cannot afford the same biological margin that endosseous systems provide. This is why prosthetic design decisions — including the "bridge on stilts" concept, the six-pillar standard, and the biological space requirements discussed in Chapter 9 — are not merely aesthetic preferences but clinical imperatives.

Clinical Note

Never use a bridge design that compresses the regenerated tissue beneath it. Even if the functional result is slightly less ideal with a "bridge on stilts" design, the biological benefit — and

the patient's ability to clean effectively — make it the only acceptable long-term solution. Priority: hygiene over aesthetics.

11.7 The Evidence for Non-Contact Pontic Design

The “bridge on stilts” philosophy is not merely theoretical — it is supported by clinical evidence. A split-mouth randomised controlled trial by Gong and colleagues (2023) directly compared plaque accumulation on the fitting surface of full-arch implant-supported fixed prostheses with contact versus non-contact pontic designs. Nineteen patients (20 prostheses) were enrolled, with each patient serving as their own control: one side of the arch received a non-contact pontic (test group) and the opposite side received a tissue-contact pontic (control group). Follow-up was performed at six months.

The results were clear: the percentage of the fitting surface covered by plaque was significantly lower in the non-contact group compared to the contact group (31.5 ± 15.8% vs. 43.7 ± 15.3%; $p < 0.001$). The debris index was also lower in the non-contact group, though this difference did not reach statistical significance. Importantly, nearly half of the patients in both groups reported dissatisfaction with cleaning, confirming that prosthetic hygiene remains a primary concern regardless of design — and underlining the importance of leaving maximum access for hygiene tools beneath the bridge. The authors concluded that non-contact pontic design significantly reduces plaque accumulation, supporting its use in clinical practice.

For subperiosteal implants, this evidence reinforces the “bridge on stilts” approach at every level: less plaque accumulation under the bridge reduces the chronic inflammatory load on the peri-implant tissues, which in turn protects the regenerated bone and reduces the long-term risk of peri-implant disease. Hygiene access is not a compromise of aesthetics — it is a biological investment.

11.8 Why No Full Arch Zirconium Bridge?

For full-arch rehabilitations, we currently do not recommend the use of monolithic full-zirconia bridges for several reasons.

First, as previously discussed, zirconia is an extremely rigid material that transfers occlusal forces directly to the supporting structures, whereas resin-based restorations can absorb part of these stresses. This stress-absorbing effect may be particularly advantageous in subperiosteal implant rehabilitations.

Second, it occasionally becomes apparent during surgery that achieving a completely passive fit of the definitive prosthesis may generate residual stresses either within the implant framework or within the prosthetic structure itself. In such situations, a titanium framework is better able to accommodate these stresses and facilitates the achievement of passive fit, whereas excessive tension within a monolithic zirconia prosthesis may increase the risk of ceramic fracture.

Furthermore, because these restorations are typically FP3 prostheses, they often require a substantial volume of artificial gingiva and prosthetic material. Full-zirconia prostheses therefore tend to be bulkier and heavier than titanium frameworks supporting resin teeth.

Another important consideration is the current trend toward highly compressive full-zirconia prostheses that rest directly on the mucosa and leave virtually no space for oral hygiene procedures.

At present, there is insufficient long-term evidence regarding these designs. Their application in subperiosteal implant therapy appears particularly challenging, as soft tissue remodeling and gingival recession may occur following surgery.

In addition, excessive compression of the soft tissues may compromise the biomaterials placed during surgery, potentially interfering with the regenerative processes that are essential for the long-term integration of the implant. Consequently, this concept appears difficult to apply to subperiosteal implants.

Finally, we generally prefer to avoid the fabrication of new definitive prostheses after surgery. Whenever a new restoration becomes necessary, it is essential to obtain highly accurate records, either through conventional plaster impression techniques or by using photogrammetry for digital impressions. These techniques can achieve accuracy approaching 20 microns and help ensure the highest possible degree of passive fit of the definitive framework.

Although we continue to work on the evolution of these concepts, our current preference is to deliver a definitive titanium framework that the patient will retain throughout life, while allowing for possible soft tissue remodeling over time. In our opinion, this remains the most predictable solution currently available.

More importantly, we believe that treatment concepts developed for conventional endosseous implants cannot simply be transferred to subperiosteal implants. These implants represent a distinct biomechanical and biological entity, and it is therefore essential to approach these treatments with a new perspective.

References

Gong Z, Lin Y, Di P. Plaque accumulation on the fitting surface of full-arch implant-supported fixed prostheses with contact or noncontact pontics: A split mouth randomized controlled trial. Journal of Esthetic and Restorative Dentistry. 2023;35(7):1077-1084.

Margvelashvili-Malament M, Eckert SE. Prevalence of peri-implant diseases in fully edentulous patients restored with four-implant-supported fixed full-arch prostheses: a literature review. Front Oral Maxillofac Med. 2022;4:17.

Chapter 12 — Pillar 9 — The Digital Workflow

The HUG® Concept is, at its core, a digital system. Every component — implant body, cutting guide, replica, prosthetic bridge, mechanical evaluation — originates from patient data and is validated before a single piece of titanium is manufactured. Pillar 9 describes the secure, integrated digital infrastructure that makes this possible.

12.1 From Patient Data to Surgical Kit

The HUG® workflow begins with CBCT imaging and intraoral scanning. Patient data is uploaded to Biotech Dental's secure digital platform, www.biotechgalaxy.com. This platform is GDPR-compliant and hosted on servers designed for medical data — unlike general file transfer services that lack the security requirements for sensitive patient information.

From the uploaded data, the design team produces: the CBCT-based bone model; the digital implant design adapted to patient anatomy; the cutting guide integrated with the planned implant position; the pterygoid guide (for maxillary cases); the prosthetic bridge design; and the PMMA replica. All components are designed as an integrated system — not independently.

Figure 12.1 — The Biotech Dental digital platform (biotechgalaxy.com): GDPR-compliant medical data platform. Once the design is complete, the surgeon reviews it using MedPrint® software — a 3D viewer allowing rotation, layer visibility toggling, and transparency adjustment. Superior to static 2D PDF review.

12.2 The Dual-Scan Protocol: Transferring Patient Data

To collect and transfer patient data, the HUG® Concept uses the dual-scan protocol — the same approach used in guided implant surgery. Radiopaque markers are placed on the patient's existing prosthesis. The prosthesis, the opposing arch, and the occlusion are then captured using an intraoral scanner. Subsequently, the patient undergoes a large-field CBCT with the prosthesis seated in occlusion and the markers in place. We also performed additional tests, which demonstrated the importance of acquiring an additional CBCT scan of the prosthesis alone with radiopaque markers, as this further improves the accuracy of the protocol.

The design engineer then matches the intraoral scan and the CBCT data using these radiopaque markers as registration points and performs a segmentation — the conversion of DICOM files into STL format. This produces accurate 3D models of the bone, the soft tissue envelope, and the prosthetic relationship, which form the basis for the digital implant design.

Figure 12.2 — The dual-scan protocol for HUG® case data acquisition. Radiopaque markers are placed on the prosthesis, which is scanned with an intraoral scanner and simultaneously captured in a large-field CBCT. The engineer uses the markers to register and match both datasets, then performs segmentation (DICOM to STL conversion) to produce the 3D models used for implant design.

12.3 The Importance of Data Accuracy

The accuracy of a custom-made subperiosteal implant begins long before the design phase. One of the most critical steps is the segmentation process, which consists of converting DICOM data from the CBCT scan into a three-dimensional STL model. The quality of this transformation directly influences the passive fit and overall accuracy of the final implant.

Beyond technical expertise and software performance, one of the major sources of inaccuracy is the presence of imaging artifacts and metallic scatter caused by residual metallic restorations, root fragments, retained implants, or other radiopaque structures. These artifacts can alter the reconstruction of the bone surface and compromise the precision of the implant design.

For this reason, our protocol systematically favors treatment on fully edentulous arches free of residual metallic elements. This approach not only improves the reliability of the digital workflow but also facilitates soft tissue management, as discussed in the dedicated chapter on soft tissues. Consequently, we generally avoid immediate extraction and implantation protocols when using subperiosteal implants, preferring to work on healed edentulous ridges whenever possible.

12.4 Design Validation with MedPrint®

When the design is complete, the surgeon receives access to the project through the online MedPrint® software. This tool is specifically designed for medical 3D design validation. The surgeon can rotate the implant in three dimensions, toggle the visibility of individual components (implant body, screws, guide, bridge), and adjust transparency to see through the bone model to the implant inside.

This level of interactivity is qualitatively different from reviewing static 2D PDF. A two-dimensional view of a three-dimensional custom implant cannot confirm the critical spatial relationships between the implant, the bone, and the tissue anatomy. MedPrint® provides validation that is both comprehensive and clinically meaningful.

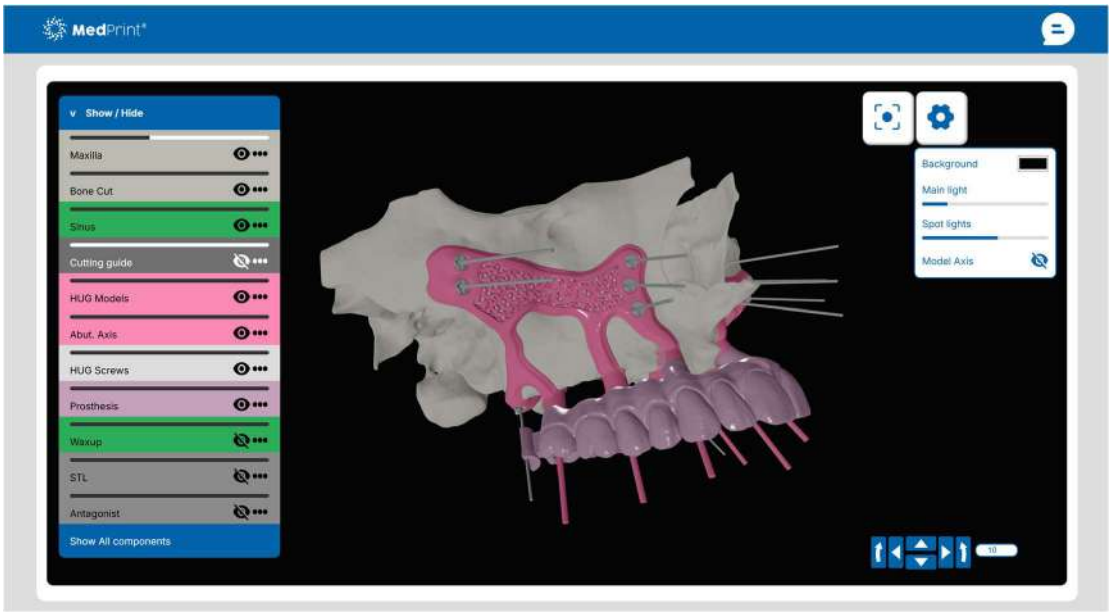


Figure 12.3 —Validation of the HUG ® implant design using the MedPrint® software, allowing three-dimensional assessment of implant positioning, fixation screw orientation, cutting guide, and prosthetic integration before manufacturing.

> **Clinical Note**
>
> *Take the time to validate the design thoroughly in MedPrint®. Check the position of every screw, the depth of the implant relative to the bone surface, the trajectory of the pterygoid screw. This is the last checkpoint before manufacturing — changes after this point are difficult and costly.*

12.5 The Pre-operative Planning Report

Before surgery, a complete planning report is provided for every case. This report specifies: the length and diameter of each fixation screw; the recommended order of screw placement (to achieve passive, sequenced implant seating); the angulation of each screw; and a colour-coded visual map of the implant with numbered screw positions.

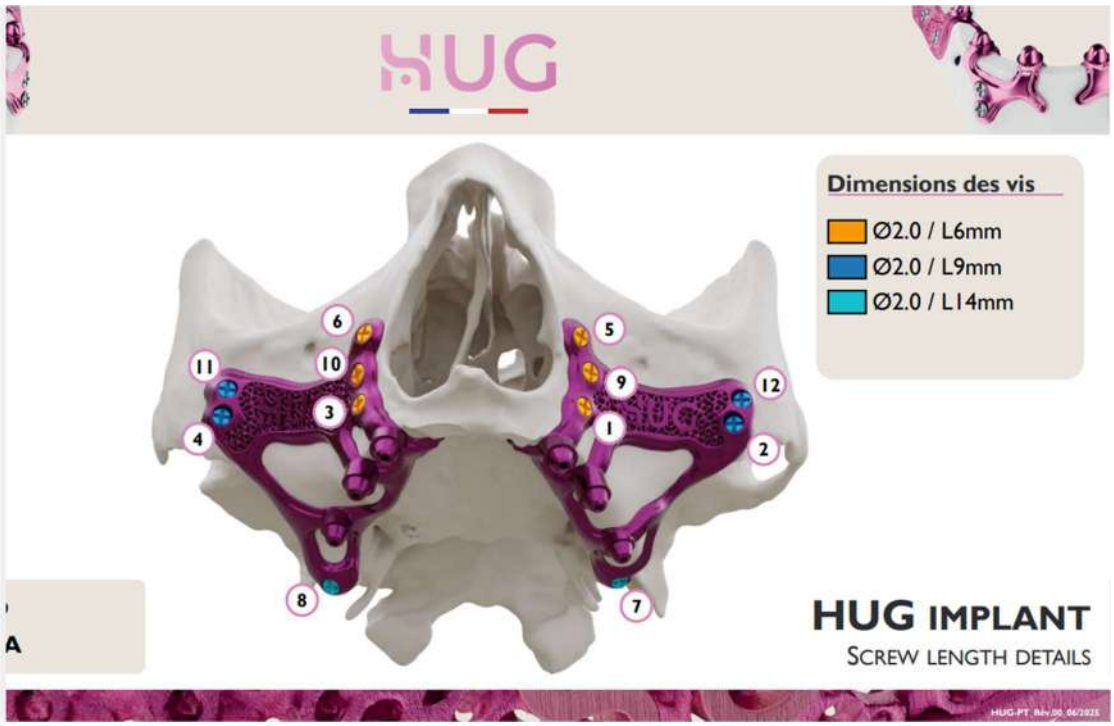


Figure 12.4 — Pre-operative planning report for a HUG® case showing the colour-coded screw placement map with numbered sequence (left) and the corresponding 3D model view with screw positions and directions (right). The colour coding differentiates screw lengths to eliminate intraoperative confusion, and the numbered sequence ensures progressive, passive implant seating.

The colour coding system uses different colours to distinguish screw lengths — eliminating the risk of confusing similar-looking screws during surgery. The numbered sequence ensures that the implant is drawn down onto the bone surface progressively and passively, without creating internal stress or deformation.

12.6 Production Oversight

The biotechgalaxy.com platform also allows the surgeon to follow the production process in real time. Each manufacturing step is tracked on the platform. The surgeon can see the status of their implant and anticipate the delivery date.

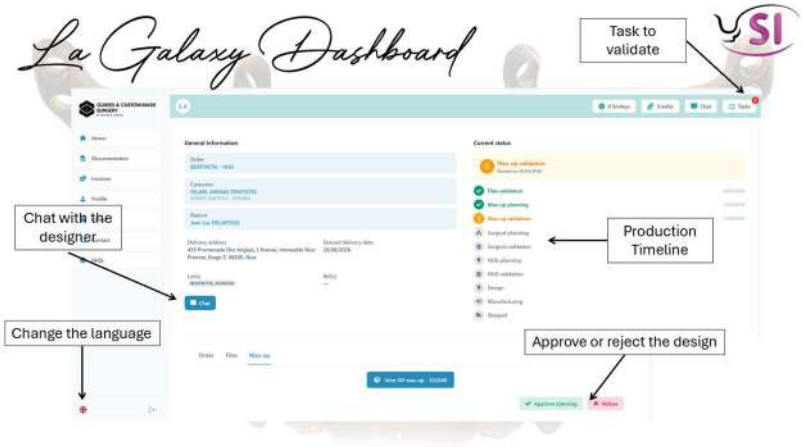


Figure 12.4 —The Galaxy Dashboard allows clinicians to review and approve the HUG implant design, communicate with the engineering team, monitor the production timeline, and follow the progress of each case from planning to delivery.

A chat function is also integrated into the platform, allowing the surgeon to communicate directly with the design team during the implant design review process. If the surgeon identifies a modification request — regarding screw position, arm angulation, or any other design parameter — the chat provides a direct, documented channel to convey this feedback to the designer. This bidirectional communication eliminates ambiguity, reduces the risk of misinterpretation, and ensures that the final design reflects the surgeon's clinical intent precisely. It also creates a traceable record of all design decisions, which contributes to clinical governance and accountability.

This transparency is not merely a convenience feature. It represents a commitment to traceability — the ability to identify exactly what was done to a specific implant, when, and by whom. In the event of a clinical question arising after placement, this information is retrievable and documentable.

12.7 The Finite Element Report

As described in Chapter 6 (Pillar 3), every HUG® implant undergoes patient-specific finite element analysis (FEA) before manufacturing. Two complementary simulations are systematically performed.

First, a fatigue analysis is conducted by applying repeated cyclic loads of 200 N, corresponding to masticatory forces, over a simulated period of 15 years. This test evaluates the risk of long-term fatigue failure and identifies potential areas of mechanical weakness.

Second, a static analysis is performed by applying a unilateral load of 500 N, representing an extreme occlusal situation. This simulation assesses the risk of permanent deformation and verifies that stresses remain within the elastic limits of the titanium structure.

Only implants that successfully pass both analyses are validated for manufacturing and clinical use, thereby ensuring adequate long-term mechanical reliability and patient safety.

The FEA report is included in the patient file on the platform. It can be presented to the patient as part of the informed consent process and shared with colleagues for case review.

Biotech Dental is currently one of the only companies performing individualized finite element analysis for every subperiosteal implant case. This distinguishes the HUG® Concept not only commercially but scientifically: it is the one of the only subperiosteal systems with documented, patient-specific mechanical validation for every single device placed.

The Digital Workflow — Key Advantages

1. GDPR-compliant platform designed for medical device data — not general file transfer services
1. MedPrint® 3D validation: superior to 2D PDF review, with rotation, transparency, and layer control
2. Patient-specific FEA report included for every case
3. Colour-coded, numbered pre-operative screw planning report
4. Real-time production tracking and full traceability
5. Integrated design of implant, cutting guide, replica, and prosthesis as a single validated system

References

1. Subperiosteal Institute / Biotech Dental. HUG® Digital Workflow Documentation — MedPrint Platform Overview. Internal document. 2025.
2. Subperiosteal Institute / LBA / Université Gustave Eiffel / GLAD Medical / Biotech Dental. HUG® Design Evaluation — Numerical Assessment: Influence of Thickness on Implant Mechanical Performance. Internal report, May 2025.

Chapter 13 — Implant Anatomy & Technical Specifications

Understanding the anatomical design of the HUG® implant is not an academic exercise — it is a prerequisite for safe and effective surgical execution. The geometry of the maxillary and mandibular implants, the choice of fixation zones, and the dimensional specifications of the prosthetic connection are the physical embodiment of everything described in the nine pillars.

13.1 Maxillary HUG® — Anatomical Design

The maxillary HUG® implant consists of a main body — the lattice structure — from which three extensions. Each extension extends to one of three fixation zones: the maxillary zygomatic process, the edge of the pyriform opening, and the pterygomaxillary suture (which accommodates the pterygoid anchorage screw). Each extension contains drilled holes to receive 2.0 mm osteosynthesis screws, with 2.4 mm rescue screw holes available if needed.

These three fixation zones were chosen for a specific biological reason: they exhibit low resorption rates over time. While the alveolar process undergoes progressive resorption following tooth loss, the zygomatic process, pyriform rim, and pterygoid region maintain their anatomical dimensions throughout adulthood. Anchoring the implant in these zones ensures that the fixation points remain stable over the long term, even as surrounding bone continues to remodel.

Figure 13.1 — Maxillary HUG® design: main body (lattice) with three extensions. 1: zygomatic process anchor. 2: pyriform opening edge anchor. 3: pterygomaxillary suture / pterygoid anchor. Each extension is pre-drilled for 2.0 mm osteosynthesis screws. Top: intraoral view with anodized titanium. Bottom: planning model in purple.

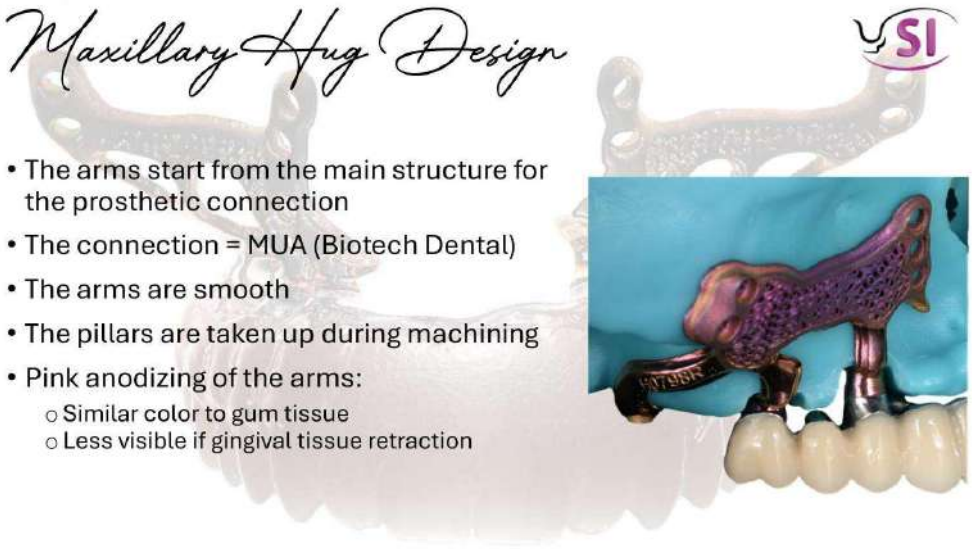


Figure 13.2 — Maxillary prosthetic arms: smooth-surfaced arms emerging from the main lattice body, with MUA (Biotech Dental) prosthetic connection. Arms are refined by milling after printing to achieve connection precision. Pink anodization of the arm: matches gingival tissue colour, reduces aesthetic impact of recession.

13.2 Dimensional Specifications

The following specifications define the standard HUG® implant. Individual patient implants may vary slightly in arm length and angulation to accommodate anatomy, but all will conform to these core dimensional parameters.

Parameter	Value	Clinical Significance
Lattice type	Gyroid TPMS, 50% porosity	Optimal osseointegration and mechanical strength balance
Lattice cell size	2 mm	Optimal for vascularisation and cell penetration
Arm width	4.5 mm	Prosthetic connection with adequate access
Arm thickness	1.5 mm	Mechanical safety with minimal tissue compression
Fixation hole diameter	2.5 mm	Accepts standard 2.0 mm and rescue 2.4 mm screws
MUA platform width	4.9 mm	Standard Biotech Dental MUA connection
Material	Ti-6Al-4V Grade 23 ELI	Superior ductility, fatigue resistance, biocompatibility
Surface treatment	Rosé anodization, ~140 nm oxide layer	Improved osseointegration and gingival aesthetics

Table 13.1 — Standard HUG® implant dimensional and material specifications.

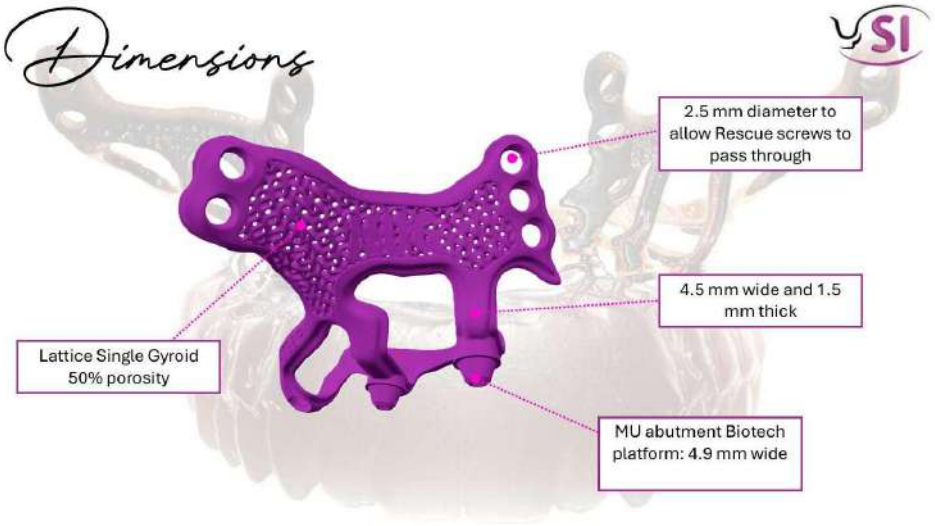


Figure 13.3 — HUG® implant dimensions illustrated on a maxillary model: lattice single gyroid 50% porosity; fixation hole 2.5 mm diameter (rescue screw compatible); arm 4.5 mm wide and 1.5 mm thick; MUA Biotech platform 4.9 mm wide.

13.3 Mandibular HUG® — Anatomical Design

The mandibular HUG® design places the lattice body on the vestibular surface of the mandibular ridge. A lingual framework connects the two sides, providing structural rigidity. Three extension zones provide fixation: the posterior vestibular trigone, the outer oblique line of the mandible, and the mandibular symphysis (anterior to the mental foramen).

The vestibular placement of the lattice is deliberate: it positions the osseointegration-promoting structure where it has direct contact with the vestibular cortex, which is the most accessible and mechanically suitable bone surface in the atrophic mandible.

Concerning the necessity of a lingual bar, this remains a matter of debate. Indeed, the literature reports a high incidence of soft tissue recession on the lingual aspect of mandibular subperiosteal implants. Whenever possible, we therefore attempt to avoid the use of lingual connecting bars. Once again, the design and development of these implants always represent a compromise between mechanical and biomechanical requirements on one side and biological considerations on the other.

From a mechanical standpoint, a lingual bar may provide additional rigidity and improve load distribution. However, from a biological perspective, it may increase the risk of soft tissue complications and lingual exposure. In complete-arch rehabilitations, we frequently design the mandibular implant in two or three independent segments connected by the definitive prosthesis. This approach reduces the need for a lingual bar while maintaining adequate mechanical stability.

In unilateral cases, a lingual extension may be more beneficial because of the reduced overall rigidity of the implant. Nevertheless, in cases of severe mandibular atrophy, the insertion of the mylohyoid muscle along the internal oblique ridge often prevents the placement of a lingual bar, making such a design anatomically impossible.

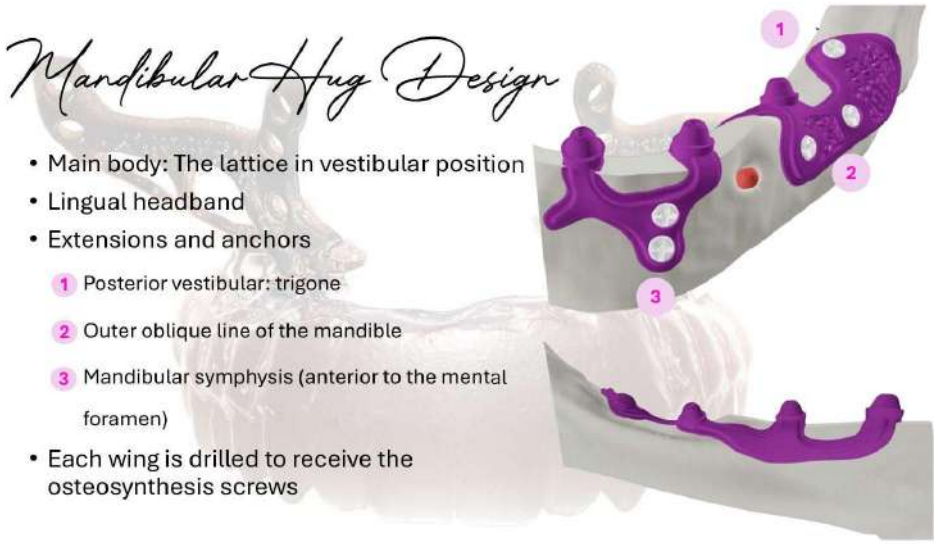


Figure 13.4 — Mandibular HUG® design: vestibular lattice (main body), lingual connector, and three fixation extensions: 1: posterior vestibular trigone. 2: outer oblique line. 3: mandibular symphysis (anterior to mental foramen). Each extension drilled for osteosynthesis screws.

13.4 Full-Arch vs. Partial Configurations

For full-arch treatment, both maxillary and mandibular HUG® systems are designed to support six prosthetic abutments. The occlusal view of both systems confirms that the six pillars are distributed across the arch in a pattern that optimizes force distribution and prevents cantilever overloading.

For partial cases, a two or three-pillar design is used, with the option of adding a cantilever extension to reposition the posterior pillar away from adjacent natural teeth. The cantilever option reduces the risk of creating bone cuts that could weaken the mesial tooth, which is an important consideration in partial rehabilitation cases.

Figure 13.5 — Full-arch configuration: maxillary (left) and mandibular (right) HUG® systems in occlusal view. Six prosthetic pillars standard for full-arch treatment. Force distribution across all six MUA connections prevents overloading and provides redundancy if one pillar is compromised.

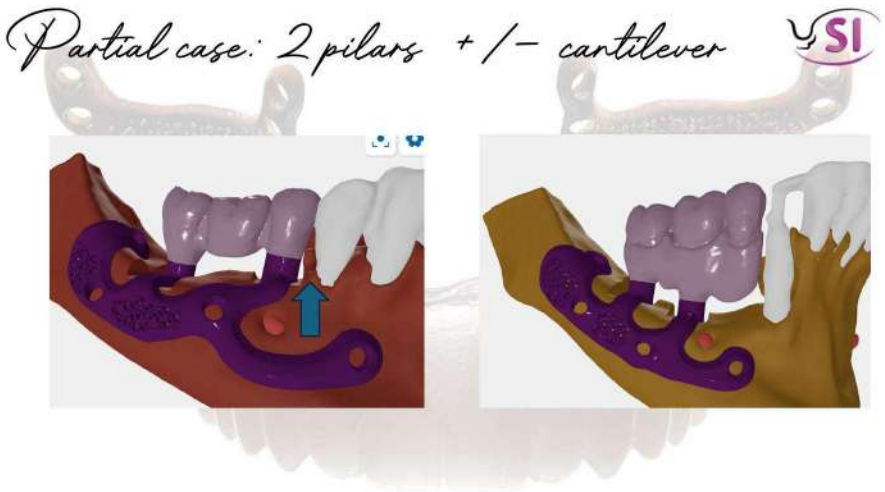


Figure 13.6 — Partial case configuration: two prosthetic pillars, with (right) or without (left) a cantilever distal extension. The cantilever option positions the distal pillar more posteriorly without requiring bone cuts adjacent to the mesial natural tooth.

13.5 Manufacturing Process

The manufacturing sequence for every HUG® implant follows a fixed protocol that ensures consistent quality across all cases. This sequence represents the physical realization of the biological and mechanical design decisions made during the nine-pillar concept development.

1. 3D printing in Grade 23 Titanium ELI via Direct Metal Laser Sintering (DMLS)
2. Heat treatment to relieve printing-induced residual stress and improve ductility
3. CNC milling of prosthetic arms to achieve precise MUA connection dimensions
4. Support structure removal — manual precision work critical to lattice integrity
5. Polishing of all non-lattice surfaces — peripheral bevel, arms, connection areas
6. Sandblasting to create a uniform surface texture on outer surfaces
7. Cleaning and acid treatment — removal of contaminants and surface activation
8. Rosé anodization — electrochemical creation of the 140 nm TiO_2 oxide layer
9. Final decontamination and sealed packaging, ready for clinical sterilization

References

1. Wang J, Huang Z, Han Z, et al. TPMS-Gyroid Scaffold-Mediated Up-Regulation of ITGB1 for Enhanced Cell Adhesion and Immune-Modulatory Osteogenesis. Adv Healthc Mater. 2025;e2404768.

2. Kundakcioglu A, Demir T, Yilmaz B. Minimum implant thickness for custom subperiosteal implants. J Prosthet Dent. 2023;129(3):452–9.

3. Hyzy SL, Cheng A, Cohen DJ, et al. Novel hydrophilic nanostructured microtexture on direct metal laser sintered Ti-6Al-4V surfaces enhances osteoblast response in vitro. J Biomed Mater Res A. 2016;104(8):2086–98.

Chapter 14 — Failure and Implant Removal

Understanding how a digital subperiosteal implant fails — and how it is removed — is not a detail. It is what makes this technique defensible to the patient and to the profession. This chapter follows one complete case, from peri-implantitis to explantation, and shows why the failure scenario is nothing like that of the historical subperiosteal implants.

14.1 The legacy of historical subperiosteal implants

We cannot present this technique without talking about failure and removal. You all have in mind the dramatic removal of historical subperiosteal implants. They were often surrounded by a mass of inflammatory tissue, with severe bone resorption.

The cause was mechanical. There was no rigid fixation. The frame moved on the bone. Contact was made through fibrous tissue, not true osseointegration. At the first infection, the whole frame mobilised. This fed the inflammation and destroyed the bony support underneath. The question, then, is simple: is it the same with digital subperiosteal implants?

14.2 Clinical case — a 69-year-old patient

This is a 69-year-old woman, a former smoker. She had two conventional implants. One to two years later, she developed rapid peri-implantitis. Both implants were removed. The bone resorption that followed is clearly visible.

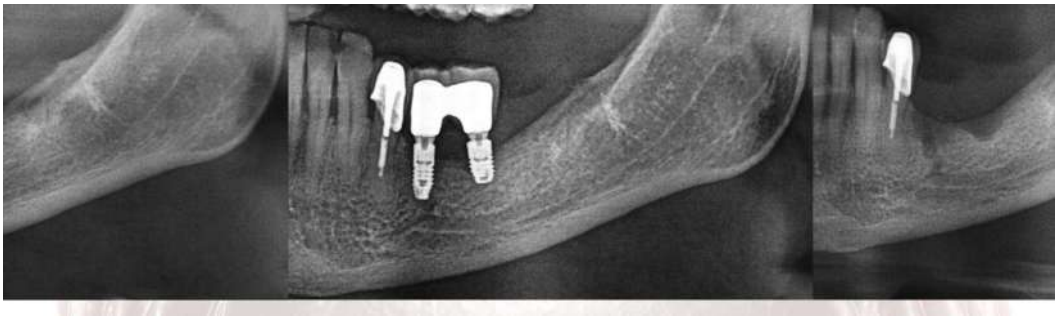


Figure 14.1 — 69-year-old former smoker. Conventional implants, rapid peri-implantitis, then bone resorption after removal.

14.3 Placement and complications

In 2022, a custom-made digital subperiosteal implant manufactured by Panthera Dental ® was placed in this patient. Several months later, recurrent infections developed, with episodes of suppuration and extraoral cellulitis originating from the mesial pillar. An initial attempt was made to preserve the implant by removing only the affected pillar; however, this approach failed to resolve the infection. Complete removal of the implant was therefore performed after 18 months of function.

The explantation procedure proved to be straightforward and required approximately 40 minutes. The lingual extension of the implant was easily sectioned because of the titanium structure, allowing the device to be mobilized and removed without difficulty. No significant inflammatory or granulation

tissue was observed, and only limited dissection of the periosteum from the implant surface was necessary.

Remarkably, no substantial bone resorption was observed beneath the implant despite the presence of chronic infection. This finding is likely related to the fixation screws, which maintained implant stability and prevented macromovement. Consequently, the infection developed without extensive mobility and bone destruction historically associated with conventional subperiosteal implants.

This case highlights an important difference between modern digitally designed and screw-retained subperiosteal implants and their historical counterparts. Even in the presence of infection, implant stability may be preserved, bone loss may remain limited, and explantation can be achieved in a relatively simple and minimally traumatic manner.

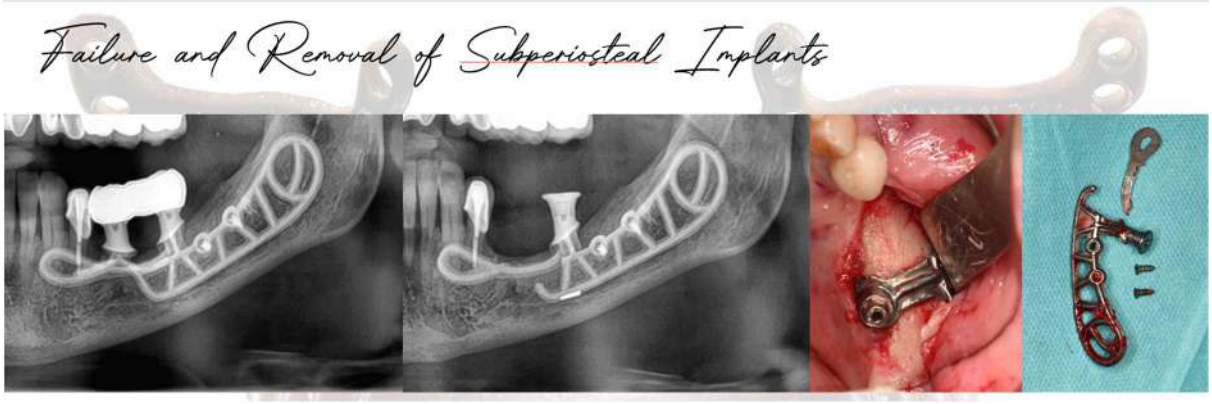


Figure 14.2 — Panthera subperiosteal implant: imaging before removal (left, centre) and the explanted implant after 18 months in function (right). The underlying bone is preserved.

The result comes down to the fixation screws. The implant was infected, but it never moved. That absence of macromovement is the major difference with the historical subperiosteal implant, and it explains why the bone underneath was preserved.

14.4 A minimally invasive, non-iatrogenic removal

This is also a major difference with conventional implant removal after peri-implantitis. Conventional implants destroy bone along their threads. Digital subperiosteal implants do not. They stay on the surface and stay still. When an infection occurs, it is mainly external cellulitis.

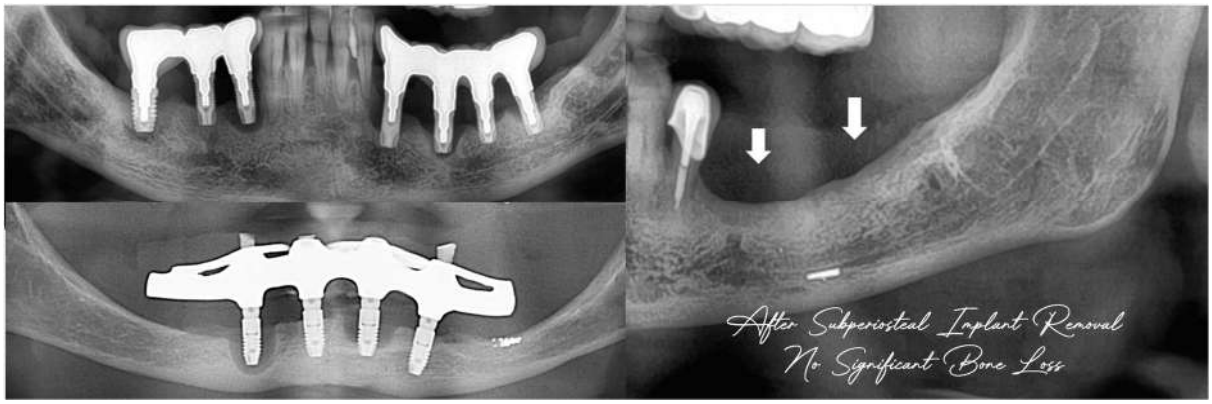


Figure 14.3 — Left: bone destruction along the threads of a conventional implant. Right (arrows): the site after removal of the subperiosteal implant, with no significant resorption.

These implants can look impressive on an X-ray, simply because of their size. In reality, the technique is minimally invasive and the solution is non-iatrogenic. It sounds surprising, but it is true: you place the implant in a single surgery, and if it fails, you remove it and return to the initial situation.

The comparison below summarises why the three families of implants behave so differently at the moment of failure.

	Historical subperiosteal	Conventional (peri-implantitis)	Digital subperiosteal (HUG®)
Fixation	None — passive support	Threaded osseointegration	Osteosynthesis screws
Movement	Micromovements	Stable while integrated	Immobile, on the surface
Inflammatory tissue at removal	Large mass	Moderate to large	Almost none if no movement
Bone resorption	Severe	Along the threads	Negligible superficial
Type of infection	Deep, fibrointegration	Peri-implant, in bone	External cellulitis
Reversibility	Destructive	Bone loss	Return to initial situation

Table 14.1 — Failure and removal compared across implant types.

14.5 Indications and clinical follow-up

We have used digital subperiosteal implants for four years, and the HUG® implant has been under development for the past two years. During this period, we have treated a wide range of clinical situations, including fully edentulous mandibles, partial edentulism, and severely atrophic maxillae.

From this experience, we believe that this technique is remarkable and provides a valuable therapeutic option for patients with severe bone atrophy. However, its indications should remain carefully selected. In our opinion, it should be reserved primarily for older patients and considered a last-resort solution when conventional implant therapy is no longer feasible. In younger patients, we still prefer bone reconstruction procedures and conventional implants whenever possible.

A last resort, not a first choice. Reserved for older patients, the digital subperiosteal implant offers a favourable risk–benefit ratio: one surgery to place, a simple and bone-sparing removal, and a return to the starting point if it fails.

At the same time, this remains a relatively new surgical approach, and longer follow-up periods are still required to fully assess its long-term outcomes. Despite these limitations, digitally designed subperiosteal implants represent a genuine paradigm shift in the treatment of severe maxillary and mandibular atrophy.

Chapter 15 — Clinical Cases

Four representative clinical cases are presented in this chapter, each illustrating a major indication for the HUG® subperiosteal implant system: the fully edentulous atrophic maxilla, the partially edentulous atrophic mandible, the fully edentulous atrophic mandible, and the posterior partially edentulous maxilla complicated by sinus pathology. Together, these cases demonstrate the versatility, precision, and clinical efficiency of the digital subperiosteal workflow.

Introduction

This section presents four clinical cases that cover the four main indications for HUG® subperiosteal implants. Each case is analysed from the initial clinical and radiographic assessment, through the digital design workflow, to the surgical procedure and postoperative follow-up. The aim is not merely to document outcomes, but to convey the method, the decision-making process, and the clinical reasoning that underpin this innovative approach to implant therapy in severely atrophic patients.

In full-arch cases, a general principle of the HUG® concept is that the delivered implant-supported restorations are definitive bridges incorporating a milled titanium framework. This has a fundamental implication: the accuracy of the data transmitted to Biotech Dental® must be optimal. Minor adjustments may be made using a wax-up; however, whenever significant changes are required—particularly regarding the vertical dimension—a complete prosthetic mock-up must be performed beforehand. There is no provisional phase: the patient leaves the operating room with a definitive prosthesis.

Case 1 — Full-Arch Maxillary Rehabilitation

Indication: Severely Resorbed, Fully Edentulous Maxilla

> This case illustrates the treatment of one of the most challenging clinical scenarios in implant dentistry: a 72-year-old patient presenting with extreme maxillary resorption, absence of bone beneath the sinuses, an oroantral communication on the left side, and virtually no residual bone in the premaxillary region. The HUG® subperiosteal system allowed definitive full-arch rehabilitation to be completed in a single surgical session.

1.1 Clinical and Radiographic Assessment

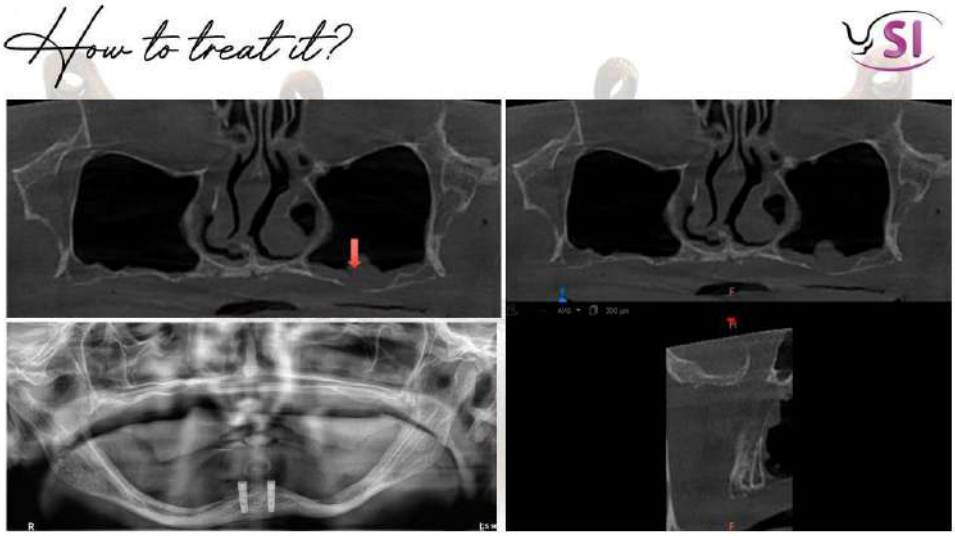


Figure 15.1 — CBCT evaluation: extreme maxillary resorption.

The patient, a 72-year-old woman, presented with extreme maxillary bone resorption. CBCT analysis confirmed virtually no residual bone in the sinus regions and an oroantral communication on the left side.

1.2 Prosthetic Planning and Mock-Up Validation

Because the bridge provided with the HUG® system is immediately definitive—incorporating PMMA teeth mounted on a milled titanium framework—it is imperative to begin with a fully validated prosthetic plan. In this case, the aesthetic assessment and the evaluation of the initial denture were of paramount importance. The existing denture was therefore remade to confirm the correct vertical dimension of occlusion as well as the aesthetic parameters.

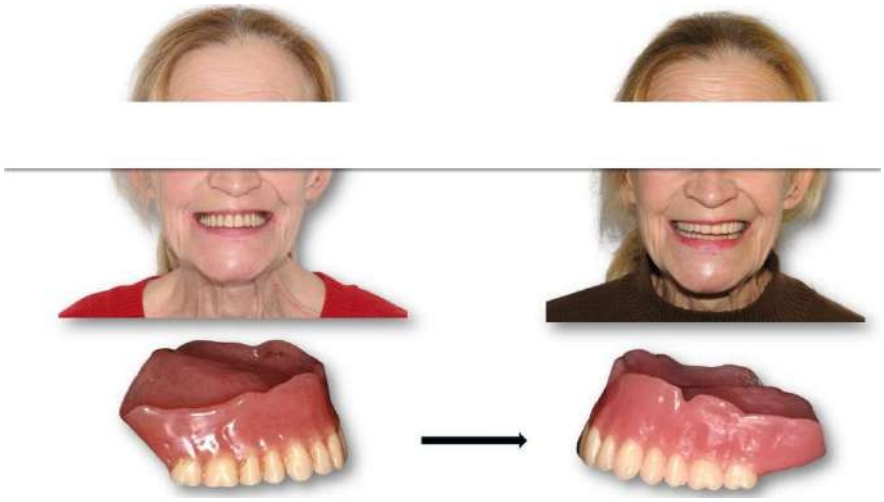


Figure 15.2 — The pre-validated wax-up and mock-up constitute the foundation of the design workflow; the bridge ultimately delivered is a definitive titanium-framed restoration.

A more affordable alternative could also have been used a 3D-printed mock-up specifically designed for the dual-scan protocol. This solution allows validation of the prosthetic parameters while reducing treatment costs and simplifying the digital workflow.

When the required adjustments are minor, a simple wax-up combined with a digital smile design is sufficient. This constitutes the first step in the validation of the prosthetic workflow.

1.3 HUG® and Prosthetic Component Design

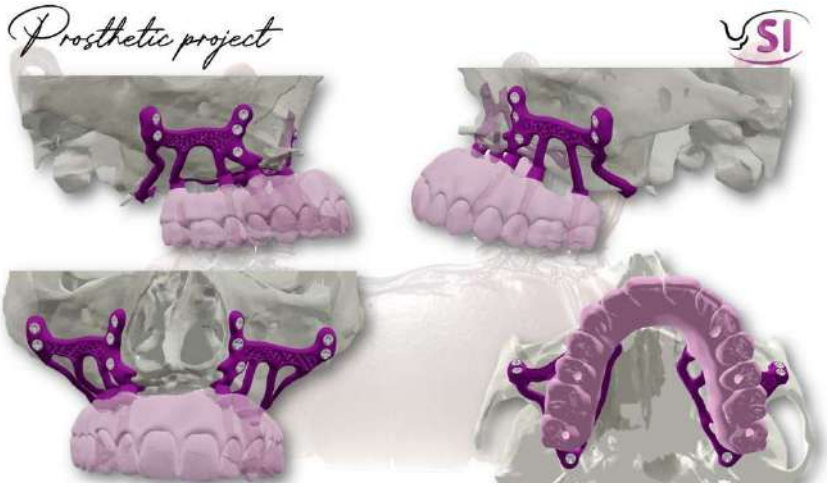


Figure 15.3 — Final prosthetic project. Note that on the occlusal view (bottom right), all screw access channels emerge through the occlusal surfaces of the prosthetic teeth.

The final prosthetic project integrates PMMA (polymethylmethacrylate) teeth with a milled titanium framework. A notable feature visible on the occlusal view is that all screw access channels are positioned precisely within the occlusal surfaces of the prosthetic teeth, regardless of the degree of bone resorption. This is only achievable through the digital workflow: abutment angulation is planned to direct access channels to optimal prosthetic positions, a constraint that would be technically impossible to meet with freehand implant placement in this degree of atrophy.

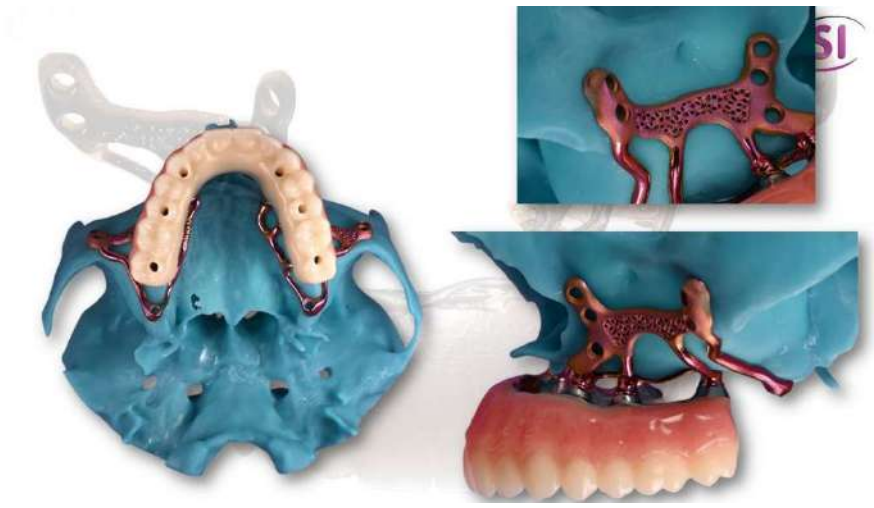


Figure 15.4 — Detail of the gyroid lattice structure and the pterygoid anchorage arm (bottom right).

1.4 Surgical Protocol

Incision and Flap Elevation

Figure 15.5 — Initial clinical situation.

The surgical procedure begins with a crestal incision, preserving a 3 to 4 mm band of vestibular attached gingiva. This gingival strip will ultimately be repositioned around the implant abutments to provide a keratinised cuff and prevent recession. A wide full-thickness mucoperiosteal flap is then elevated on both the palatal and vestibular aspects. A midline vestibular releasing incision facilitates tension-free elevation.

Dissection progresses along the nasal fossae and over the zygomatic process of the maxilla. The non-dominant hand stabilises the tissue and guides the elevation. The infraorbital foramen is identified and protected throughout. Temporary stay sutures are placed on both the palatal and vestibular flaps; this simple step — taking only a few seconds — significantly improves surgical field visibility and assistants' ergonomics and saves considerable time later in the procedure.

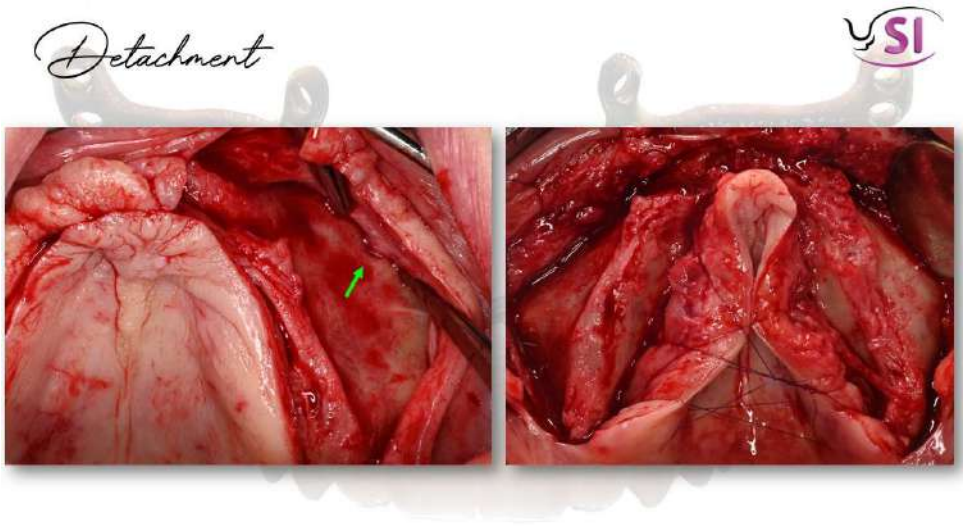


Figure 15.6 — Mucoperiosteal detachment and identification of the infraorbital foramina.

Implant Positioning and Occlusal Verification

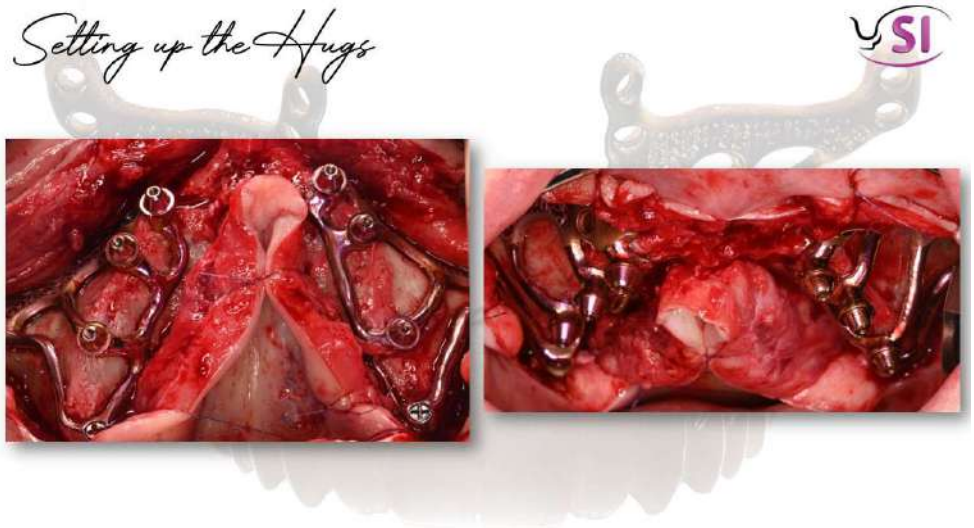


Figure 15.7 — Setting up the HUG® implants on the bone surface.

Both HUG® shells are placed on the bone surface. The anatomical fit is immediately apparent: the custom design, derived from the patient's own CBCT, ensures that the shells rest flush against the cortical surface with no interposition. The definitive bridge is then screwed onto the abutments and the patient is asked to bite, bringing both arches into centric occlusion. This critical step verifies the implant position under functional load before definitive fixation.

Fixation Sequence and Bone Grafting

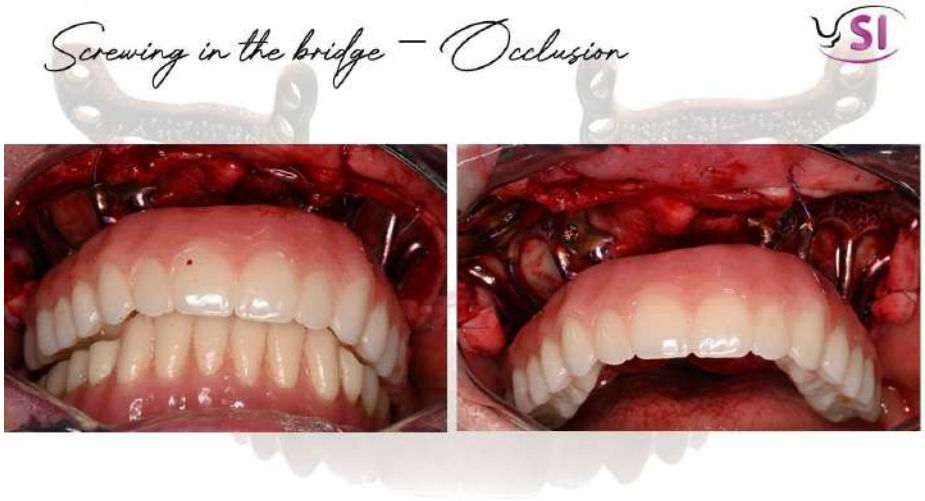


Figure 15.8 — Osteosynthesis of the HUG® implants is performed with the bridge screwed onto the abutments and maintained in occlusion.

Fixation follows the screw sequence specified in the planning report, alternating between right and left sides to maintain balanced seating pressure. Each screw is hand-tightened then torqued. The bridge is subsequently removed to allow completion of the bone grafting phase.

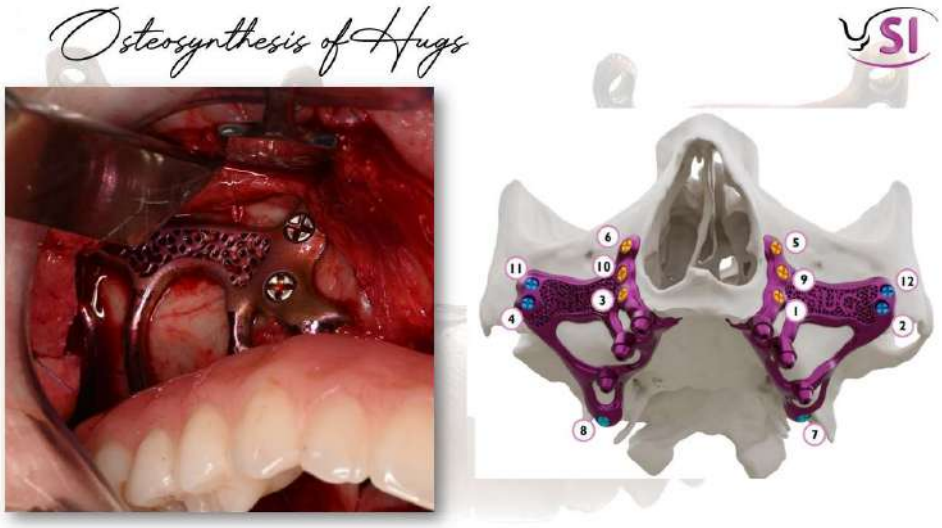


Figure 15.9 — Left: intraoperative view of screw insertion. Right: planning report indicating the recommended insertion sequence (numbered 1 to 12). The alternating right–left, cross-pattern protocol ensures balanced seating and passive fit.

After unscrewing the bridge, the surgeon confirms the firmness of the fixation by percussion and manual manipulation. The pterygoid screws are particularly important in maxillary cases: they engage the pterygoid plates posteriorly and provide a crucial posterior anchor that resists occlusal forces directed posteriorly and superiorly.

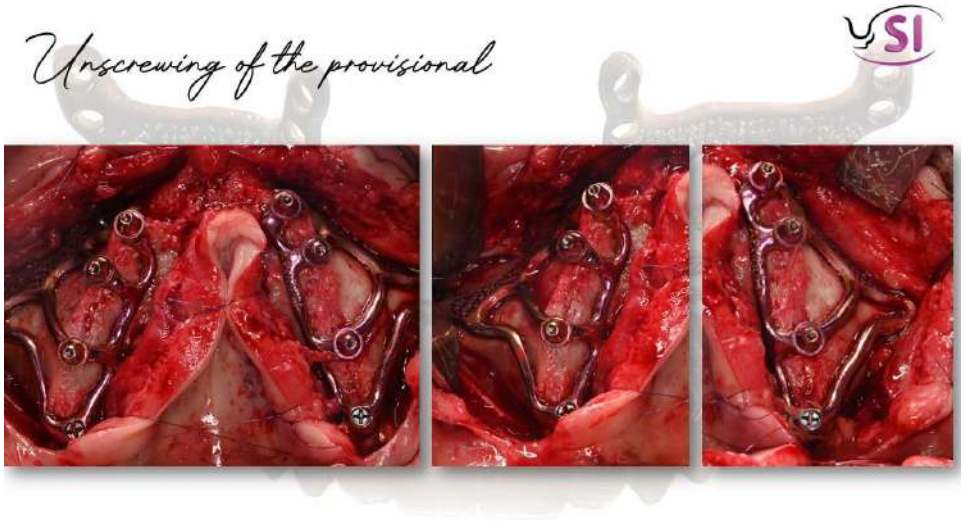


Figure 15.10 — After bridge removal. The pterygoid anchorage screw head is clearly visible in the posterior region. The entire implant assembly is rigidly fixed and immobile against the bone surface.

The implants are then covered with a bone substitute. In this case, Collapat II — a collagen matrix incorporating bovine hydroxyapatite — was used. This material fulfils a dual function: it occupies the space between the periosteum and the implant shell, preventing soft tissue collapse onto the titanium surface, and it provides an osteoconductive scaffold for new bone formation. The subsequent bone regeneration over the implant represents a paradigm shift in the interpretation of subperiosteal implants: rather than remaining purely subperiosteal, the HUG® device gradually becomes partially intraosseous. We now use a xenogeneic biomaterial instead of Collapat II to further enhance this bone regeneration.

Figure 15.11 — Bone grafting to create a biological scaffold that promotes guided bone regeneration over the titanium shell.

PRF (Platelet-Rich Fibrin) has been a routine component of our regenerative protocol for over two decades. PRF is used in this context to soak the xenogeneic bone substitute, enriching it with growth factors (PDGF, TGF-β, VEGF) that accelerate angiogenesis and early bone cell recruitment. PRF membranes are then layered over the grafted area, acting simultaneously as a biological membrane

and a vascularised fibrin scaffold. This combination synergistically enhances the regenerative environment around the implant.

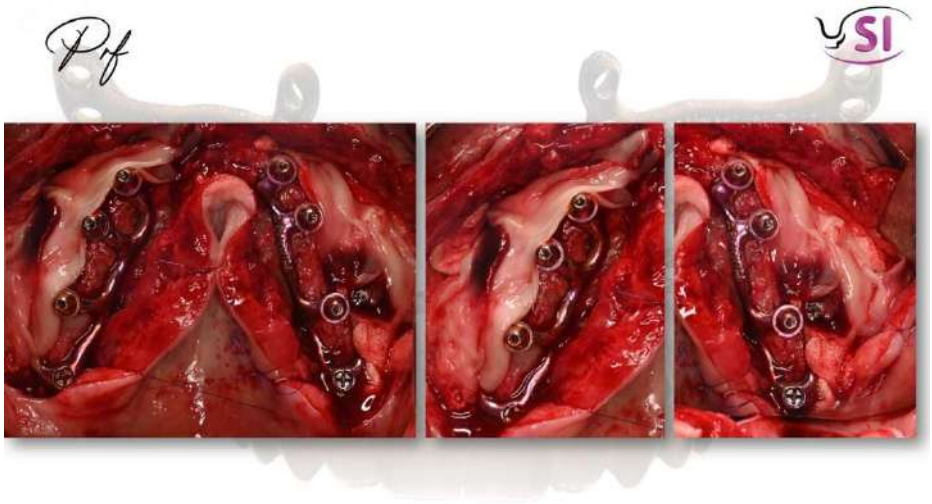


Figure 15.12 — Application of PRF (Platelet-Rich Fibrin) membranes.

Healing Caps Placement and Suturing

High-profile healing caps are placed on all multi-unit abutments. These components serve a primarily mechanical purpose during suturing: they project through the mucosal flap and allow the surgeon to adapt the tissue precisely around each abutment, ensuring a watertight seal. The attached gingival band preserved at the incision is repositioned on the vestibular aspect of the abutments.

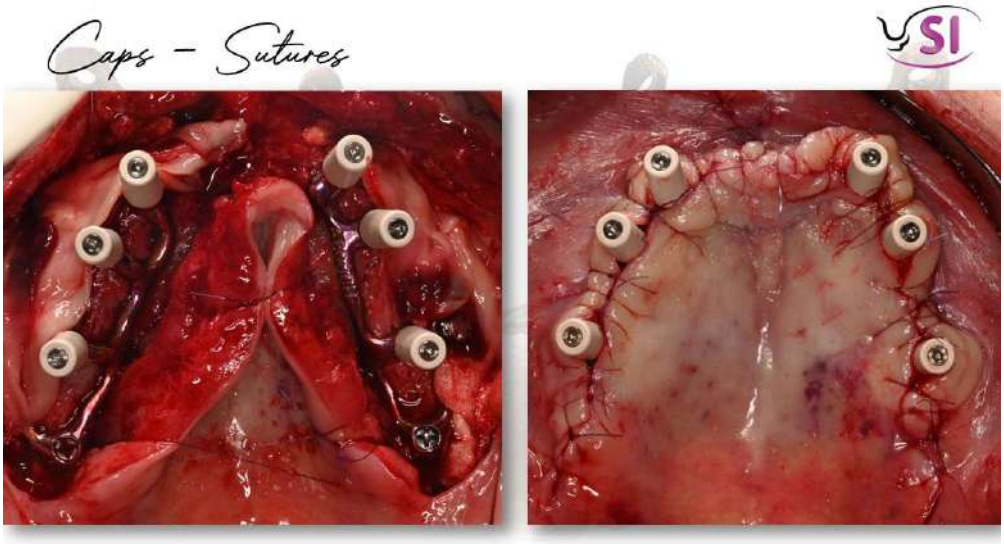


Figure 15.13 — Placement of high-profile healing caps on the multi-unit abutments.

The mucosal flaps are closed with a 5-0 resorbable monofilament suture, combining simple interrupted stitches with deep mattress sutures around each abutment to achieve a keratinised tissue cuff. The healing caps are removed, and the definitive bridge is then repositioned. Occlusion is verified, and the patient is discharged with a complete fixed maxillary restoration. The entire treatment—from an edentulous, severely atrophic maxilla to a definitive bridge—has been accomplished in a single surgical appointment.

Figure 15.14 — Final screw tightening of the definitive bridge after removal of the healing caps.

1.5 Postoperative Radiographic Assessment

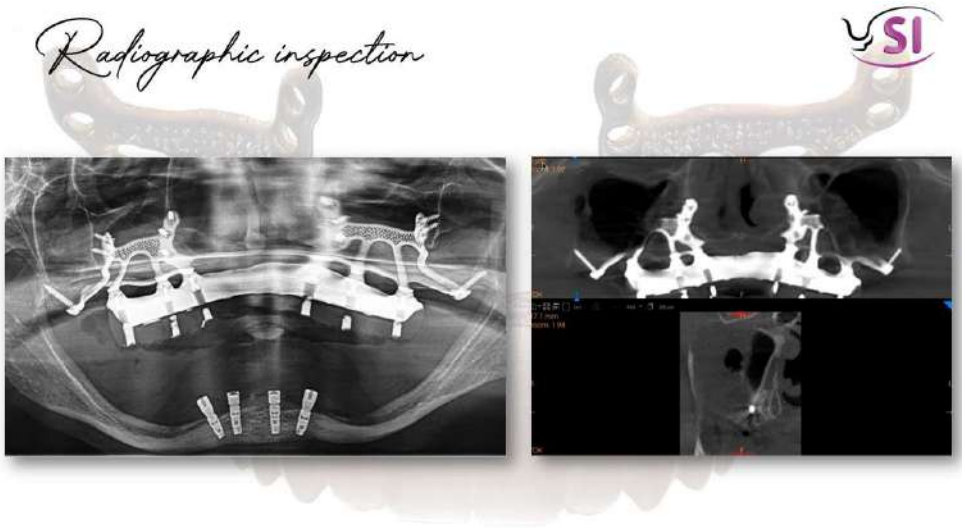


Figure 15.15 — Postoperative CBCT evaluation.

Immediate postoperative CBCT confirms the precise seating of both implant shells on the bone surface. Sagittal reformatting allows individual verification of each fixation screw: bicortical engagement is confirmed at zygomatic, pterygoid, and nasal sites. The excellent structural adaptation of the custom implant to the highly irregular bone surface — a direct result of the digital workflow — is clearly apparent.

1.6 Clinical Follow-Up and Tissue Integration

Figure 15.16 — Aesthetic integration at 3 weeks.

Three weeks postoperatively, the aesthetic integration of the bridge is excellent. Facial support is restored, lip projection is normalised, and the patient reports a significant improvement in quality of life. Clinical feedback is highly positive. The impact of a single surgical session on a patient who had spent years managing an ill-fitting maxillary denture cannot be overstated.

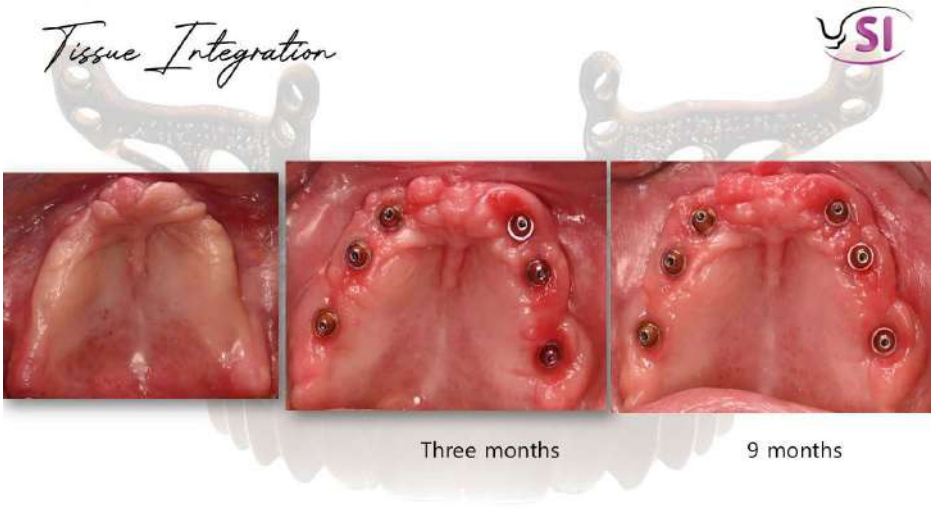


Figure 15.17 — Tissue integration at 3 months (centre) and 9 months (right).

Clinical control examinations at 3 and 9 months demonstrate stable, healthy peri-implant tissues. Percussion yields a clear, resonant sound indicative of rigid fixation. The gingival volume around the abutments has increased noticeably compared to the immediate postoperative appearance, an observation consistent with the hypothesis that the bone substitute and PRF combination promote both bone and soft tissue regeneration. This tissue gain is clinically significant: a greater volume of attached peri-implant tissue reduces muscular traction and the risk of future gingival recession.

Case 2 — Partial Unilateral Mandibular Rehabilitation

Indication: Posterior Mandibular Atrophy with Insufficient Bone Height above the Inferior Alveolar Nerve

> A 69-year-old patient with less than 6 mm of residual bone height above the inferior alveolar nerve in the right posterior mandible. The absence of mesial and distal bone peaks, combined with the patient's preference for an expedited treatment, made vertical bone regeneration impractical. The HUG® partial mandibular implant offered a single-stage alternative.

2.1 Clinical and Radiographic Assessment

Figure 15.18 — Initial situation: panoramic radiograph (left) and intraoral view of the lower right posterior quadrant (right).

The patient, aged 69, sought restoration of the posterior right mandibular region. Clinical and radiographic evaluation revealed an atrophic alveolar ridge with less than 6 mm of bone height above the inferior alveolar nerve canal. Neither mesial nor distal bone peaks were present, which would be required as anterior and posterior support for a conventional staged vertical bone regeneration procedure. The patient explicitly requested a rapid, minimally invasive treatment.

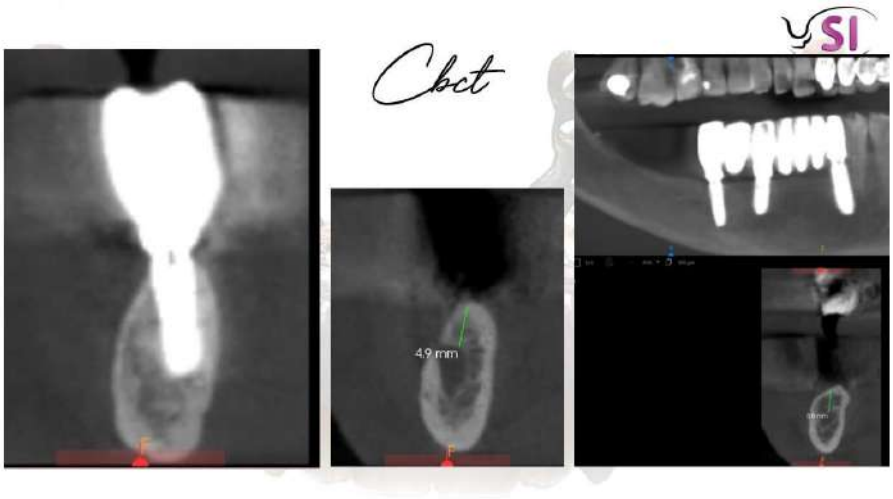


Figure 15.19 — CBCT evaluation.

CBCT analysis confirmed that the residual bone above the inferior alveolar nerve measured only 4.9 mm at its thinnest point. This dimension falls below the 7 mm safety threshold generally required for standard endosseous implant placement, and the bone morphology — thin, irregular, with no supporting peaks — is unfavourable for vertical bone regeneration. The subperiosteal approach, which bypasses the inferior alveolar nerve entirely by resting on the cortical surface of the mandible, represents the ideal solution for this clinical scenario.

2.2 Digital Design: Bone Reduction and Implant Planning

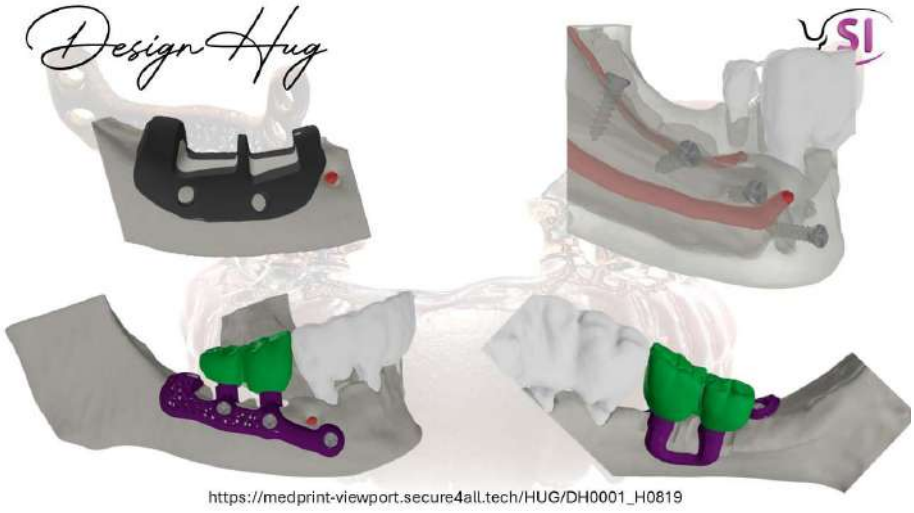


Figure 15.20 — HUG® partial mandibular implant design.

As the implant is anchored on the stable basal bone, a bone cutting guide was designed to create precise osseous slots. This enables the implant arms to be partially recessed into the bone, so that they are surrounded by bone rather than simply resting on its surface, thereby improving implant stability and promoting long-term osseointegration. This bone-embedding approach is a fundamental principle of the intraosseous subperiosteal implant concept. The design process for this partial mandibular case begins with a planned bone reduction step. This reduction also helps prevent subsequent soft tissue recession. The implant itself is then designed with a vestibular lattice structure — analogous to the gyroid TPMS used in the maxillary shells — four cortical fixation screws, and two multi-unit abutments positioned to support the planned two-unit prosthetic restoration.

2.3 Surgical Procedure

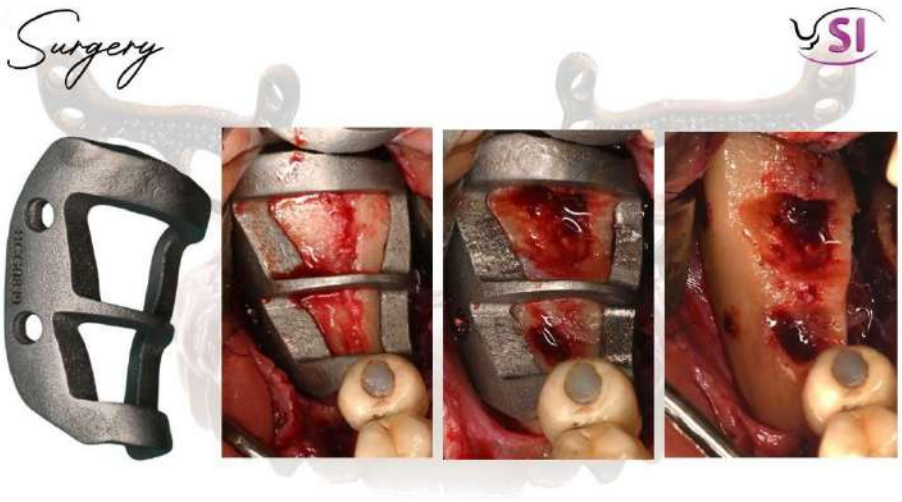


Figure 15.21 — Surgical steps: bone reduction guide (far left), guide in position with fixation screws (second), bone reduction in progress with Lindemann bur (third), and bone surface after guide removal with regularised and rounded edges (right).

The incision begins along the anterior border of the ramus and continues as a crestal incision along the alveolar ridge, with a vertical releasing incision mesial to tooth 44. A full-thickness flap is elevated.

The mental foramen is identified, and a subforaminal dissection is performed using a tunnelling curette. The lingual aspect of the flap is also elevated, releasing the mylohyoid muscle attachments. Temporary stay sutures improve visibility.

The bone reduction guide is then positioned and fixed with two small cortical screws. Bone reduction is performed first with a round zirconia bur to accelerate the process, then refined with a Lindemann bur mounted on a contra-angle. After guide removal, all bone edges are rounded and smoothed to eliminate any sharp prominences that could compromise the passive fit or cause soft tissue irritation.

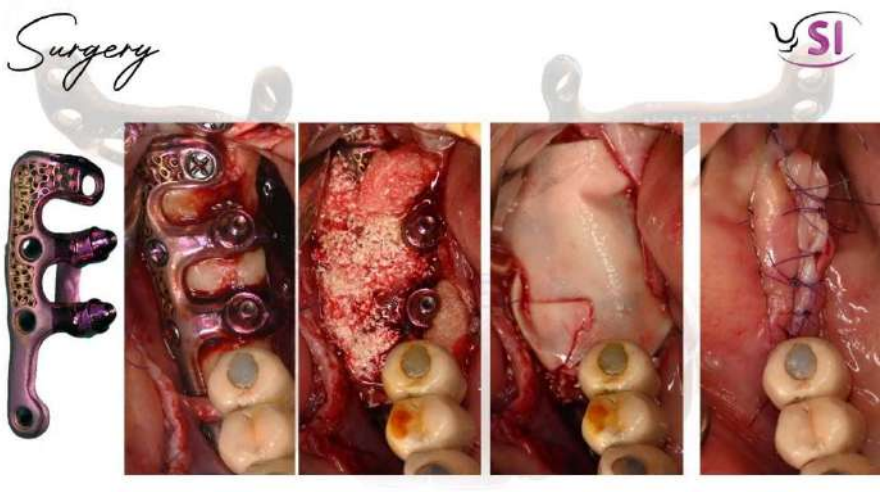


Figure 15.22 — Implant fixation, bone grafting, membrane placement. The anterior arm of the implant is positioned under the mental nerve. Sticky bone (xenograft mixed with PRF) is applied over the implant surface, followed by a resorbable collagen regenerative membrane. In partial mandibular cases, no healing caps are placed at the first stage: the abutments are buried under the closed flap to maximise bone regeneration over the implant.

Once the bone surface is prepared, the HUG® implant is positioned. It clips onto the bone and immediately demonstrates excellent primary stability. Osteosynthesis screws are inserted sequentially. Notably, in this case the anterior arm of the implant is positioned slightly below the mental nerve — an anatomical relationship that must be anticipated in the virtual planning phase and respected intraoperatively. Sticky bone — a mixture of xenogeneic bone substitute and PRF — is applied over the entire implant surface, followed by a resorbable collagen regenerative membrane. The abutments are intentionally buried: no healing caps are placed at this first stage. The flaps are sutured in a watertight manner using a 5-0 resorbable monofilament. A second surgical stage will be required at approximately four months to uncover the implants.

2.4 Radiographic Verification

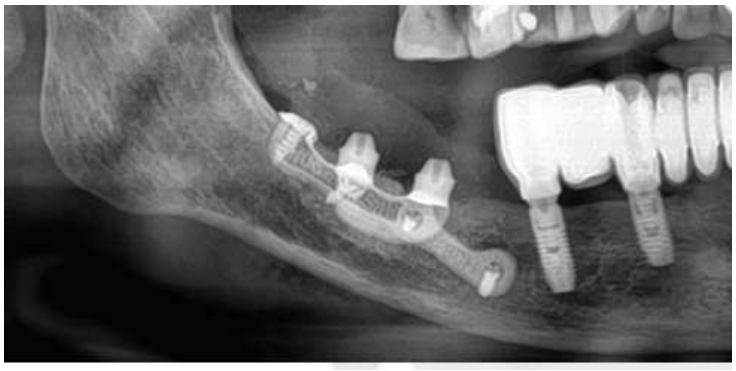


Figure 15.23 — Postoperative radiograph.

The postoperative panoramic radiograph confirms the ideal positioning of the implant: the arms rest on the cortical bone surface, well above the inferior alveolar nerve canal.

2.5 Second Stage and Prosthetic Rehabilitation

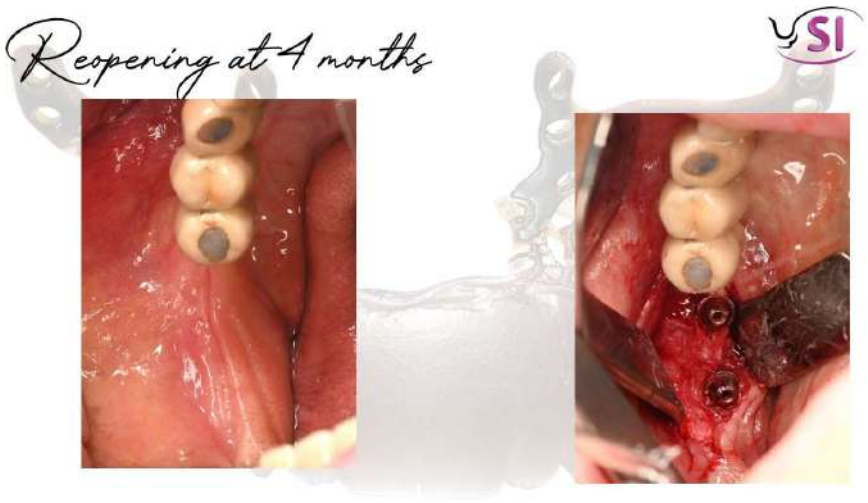


Figure 15.24 — Second surgical stage at 4 months. After flap elevation, new bone and well-vascularised tissue are clearly visible covering the implant arms.

At four months, the second surgical stage is performed. After flap elevation, well-vascularised tissue and new bone are clearly visible overlying the implant arms. This finding is clinically and conceptually significant: the HUG® implant, initially purely subperiosteal, has become partially integrated within newly formed bone. This bone coverage is ideal for long-term soft tissue stability, providing a biologically favourable foundation for the peri-implant gingiva and reducing the risk of future recession.

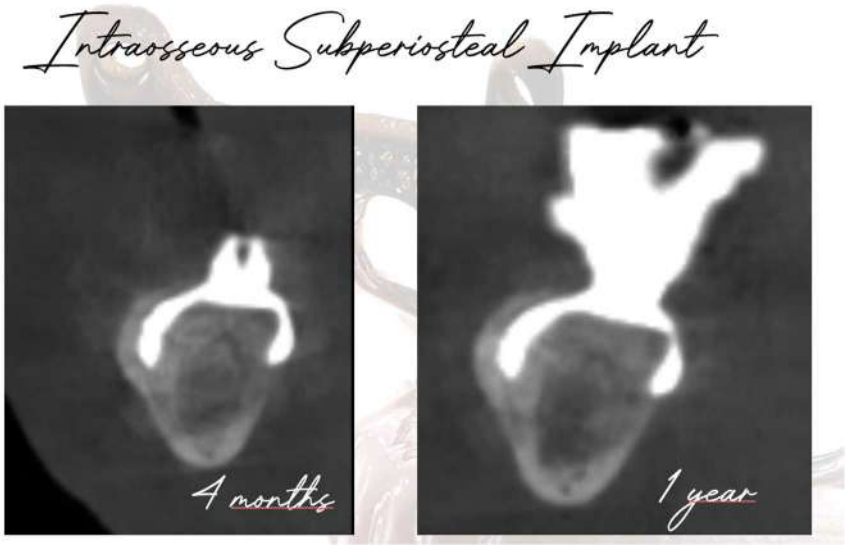


Figure 15.25 — Radiographic comparison (left to right): 4-month and 1 year postoperative. Bone regeneration above the implant arms is clearly visible.

Radiographic comparison at four months confirms new bone formation above the implant arms. This observation, reproducible across multiple cases, supports the reclassification of the HUG® device as a hybrid implant: initially subperiosteal in its placement, it progressively acquires partial intraosseous

status through guided bone regeneration. This paradigm shift has profound implications for our understanding of implant stability and long-term prognosis in this category of devices.

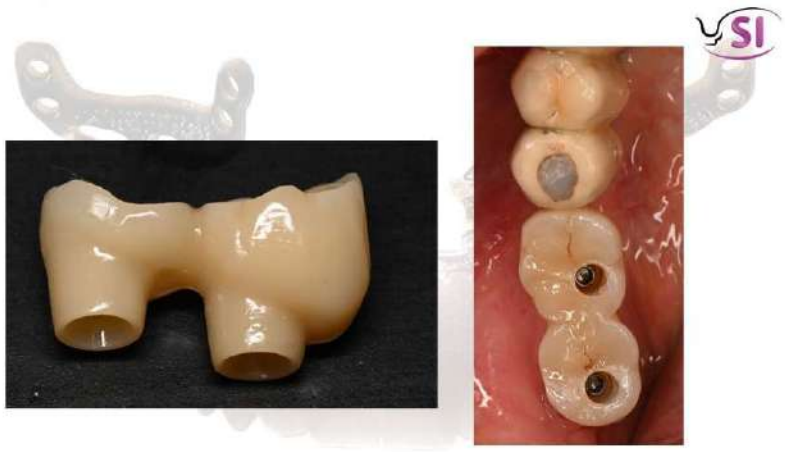


Figure 15.26 — Full Zirconium definitive crowns.

The definitive full-zirconia crowns, fabricated without titanium interfaces and screw-retained, are then delivered. They provide optimal soft tissue biocompatibility.

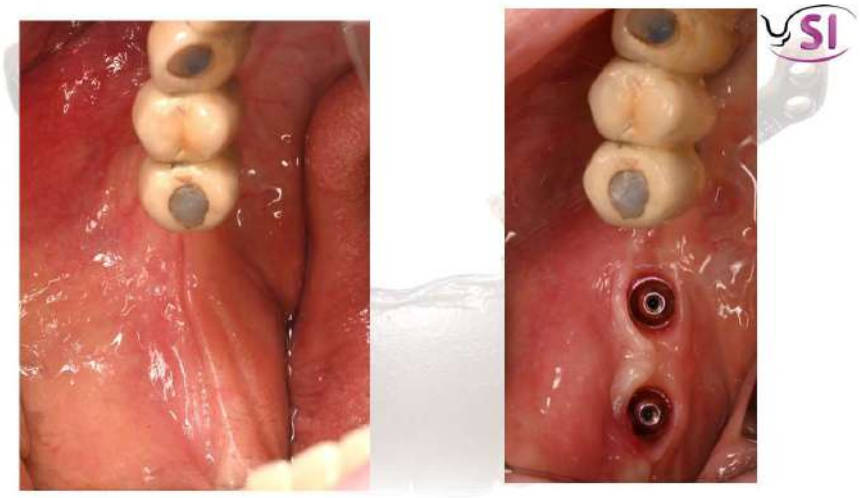


Figure 15.27 — Comparison of tissue quality between the initial and final situations: a favorable band of buccal attached gingiva is present.

The final tissue quality observed is consistently favourable. A generous band of vestibular attached gingiva surrounds the abutment area. This tissue architecture reduces muscular traction from the buccinator muscle and should contribute to long-term stability of the peri-implant gingival margin.

Case 3 — Bilateral Partial Maxillary Rehabilitation

Indication: Posterior Maxillary Atrophy with Chronic Sinusitis and Oroantral Communications

> This case introduces a clinical scenario of increasing prevalence: the patient who has already undergone sinus bone grafting and endosseous implants, only to develop peri-implantitis and chronic sinusitis necessitating implant removal. With bilateral oroantral communications and a history of sinus pathology, any new attempt at grafting is contraindicated. Bilateral partial HUG® subperiosteal implants, bypassing the sinus entirely, offer the only viable solution for restoring posterior occlusal support in this patient.

3.1 Clinical and Radiographic Assessment

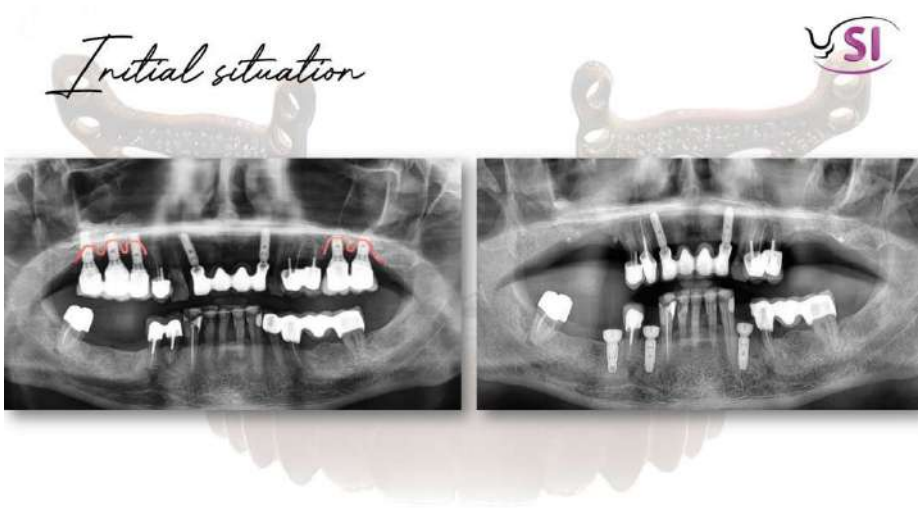


Figure 15.28 — Initial radiographic situation (left: preoperative, right: after implant removal).

The patient, an elderly male over 70 years of age, had previously undergone bilateral maxillary sinus bone grafting followed by endosseous implant placement. He now presented with terminal peri-implant disease in both posterior maxillary quadrants. The affected implants were removed. The ensuing infectious episodes resulted in chronic sinusitis and the development of bilateral oroantral communications. The patient categorically refused further sinus surgery.

CBCT analysis confirms bilateral maxillary sinusitis with opacification of both sinus cavities, bilateral oroantral communications, and virtually no residual bone above the sinus floors in the posterior quadrants. This anatomy is an absolute contraindication to further sinus surgery. Bilateral HUG® subperiosteal implants are proposed as the sole implant-based solution compatible with this clinical situation.

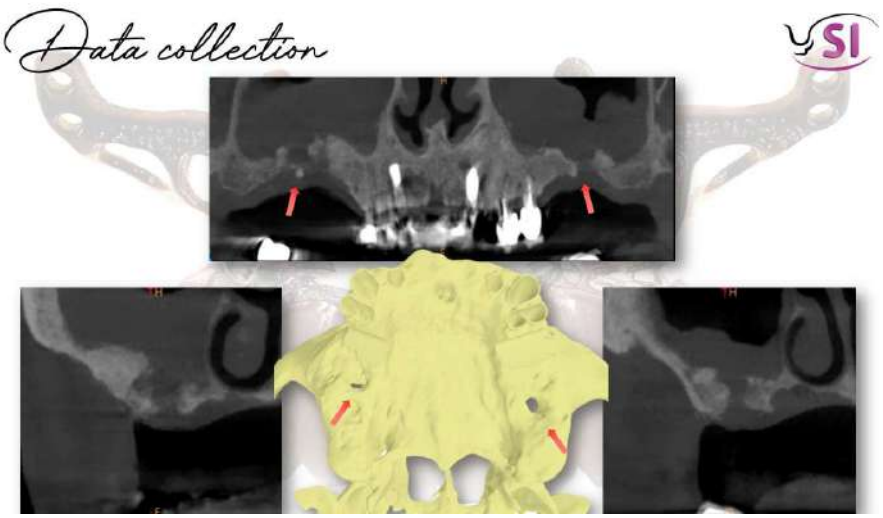


Figure 15.29 — CBCT data collection. Coronal and sagittal sections confirm bilateral oroantral communications (red arrows).

3.2 Digital Planning and Design Workflow

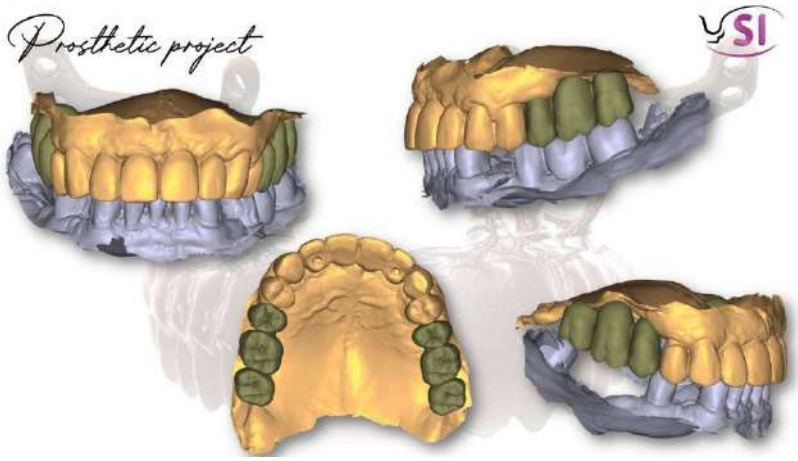


Figure 15.30 — Virtual prosthetic project (wax-up)..

The prosthetic project is established first. A virtual wax-up defines the positions of the prosthetic teeth and the required abutment locations. On both sides, the oroantral communications dictate that the abutment positions cannot be placed in the area of the communications: second premolar and second molar positions are selected on each side to bridge over the communication zones. The posterior abutment axes are slightly tilted anteriorly so that screw access channels emerge through the occlusal surfaces of the molar teeth.

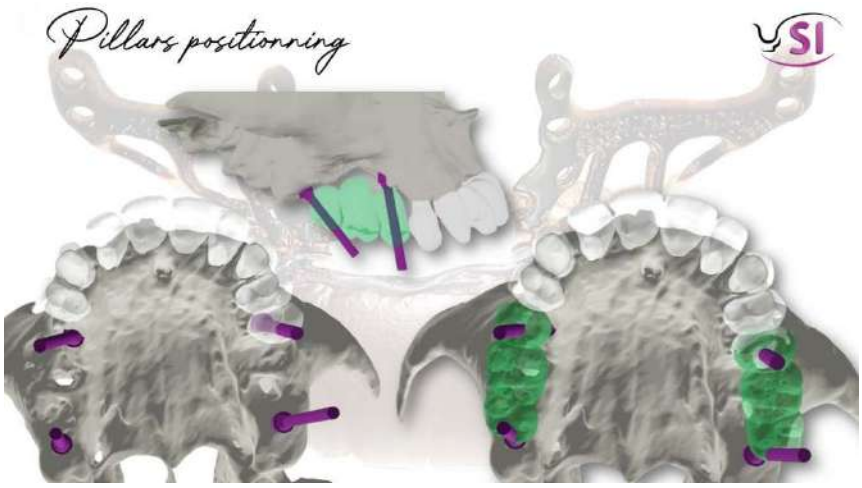


Figure 15.31 — Abutment positioning in relation to the wax-up.

This abutment planning step is central to the HUG® design workflow for partial cases: the surgeon defines prosthetically ideal abutment positions, and the design engineer then creates the implant body to connect these positions to available anchorage points on the cortical bone. The implant design adapts to the prosthetic requirements — not the reverse. This prosthetically driven approach guarantees optimal prosthetic retrievability and functional occlusion regardless of the underlying bone anatomy.

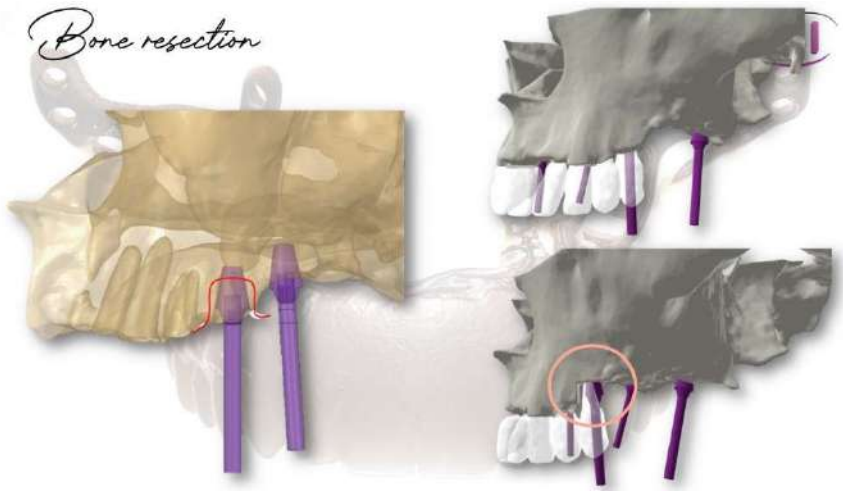


Figure 15.32 — Bone resection planning.

A bone resection guide is designed to prepare the cortical surface at the extraction site of tooth 25, converting the alveolar socket area into a flat cortical base capable of supporting the HUG® abutment. It should be noted that this simultaneous extraction-and-implantation approach was adopted because this was an early case in the development of the HUG® protocol. The current recommended practice is to extract teeth first, allow 3 months of natural healing, and only then proceed with implant placement. This interval allows the attached gingiva to regenerate spontaneously around the future abutment site, eliminating the need for a separate soft tissue procedure.

Figure 15.33 — Final HUG® implant design: bilateral partial maxillary shells with zygomatic, pterygoid, and paranasal anchorage points.

The bilateral HUG® implants are designed with three anchorage points per side: zygomatic, pterygoid, and paranasal. At the paranasal level, the design must carefully avoid any contact with the roots of the remaining anterior teeth and preserve adequate space for potential future endosseous implant placement. This forward-looking design principle — maintaining future implant options — is a fundamental aspect of the HUG® concept. The system is not conceived as a permanent exclusion of all other treatment modalities, but as a complementary approach that coexists with conventional implantology.

3.3 Planning Report and Surgical Kit

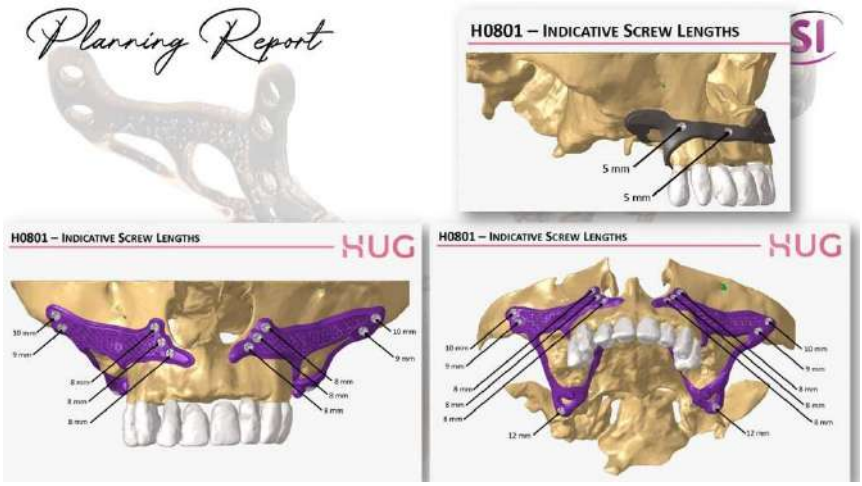


Figure 15.34 — Planning report for the partial maxillary case: screw lengths (top panels) and screw insertion axes (bottom panels) for both right and left sides. This version of the report represents an earlier iteration of the document; the current version has been further refined for clarity.

For partial cases, the surgical delivery package differs from full-arch cases: temporary PMMA bridges (one per side) are provided rather than a definitive restoration. These temporaries serve the same stabilisation and aesthetic function during the healing period, after which the patient returns to the referring laboratory for fabrication of the definitive prosthesis.

Figure 15.35 — Surgical delivery kit for partial maxillary cases: bone reduction guide, resin model of the maxilla, bilateral HUG® titanium implant shells, temporary PMMA bridges (one per side), and osteosynthesis screws. In partial cases, temporary bridges are supplied for the healing period; the definitive ceramic or hybrid prosthetic is fabricated by the referring dental laboratory after osseointegration.

3.4 Surgical Procedure

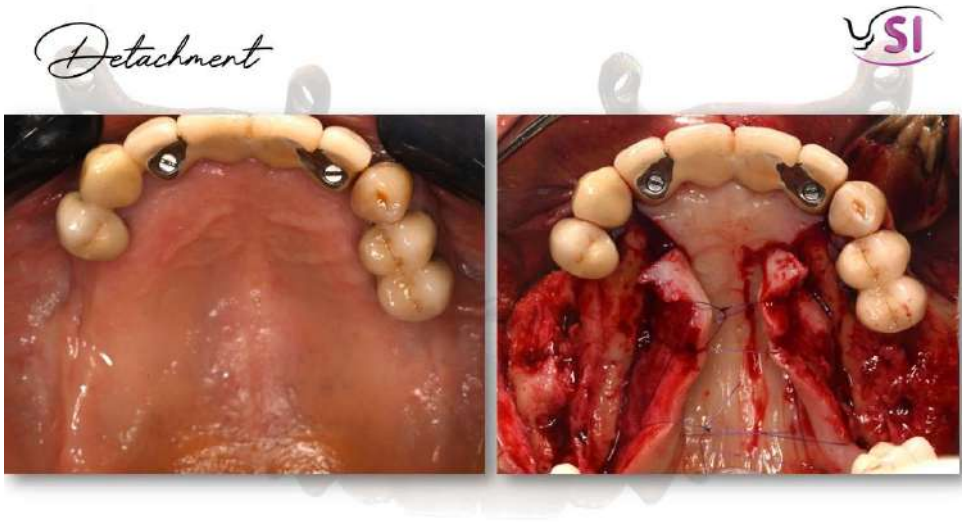


Figure 15.36 — Bilateral mucoperiosteal flap elevation. Releasing incisions on both vestibular and palatal sides provide flap mobility.

The crestal incision is made slightly palatally to preserve the vestibular attached gingiva and to avoid the oroantral communication areas. Palatal flaps are elevated first, with mesial releasing incisions. A careful partial-thickness dissection is then performed in the communication zones: a strip of connective tissue is intentionally left in situ to close the oroantral communications during subsequent flap advancement. The anterior area and zygomatic regions are dissected. All fibrous tissue is removed from the bone surface using a round bur. The infraorbital foramen is identified bilaterally.

Figure 15.37 — Bilateral positioning of bone reduction guides. Each guide is independently adapted and fixed on its respective side.

Both cutting guides are positioned and fixed bilaterally. Bone reduction is performed on each side. Following guide removal, both HUG® shells are placed. The two temporary bridges are screwed in place and the patient is asked to occlude. Once passive fit and correct occlusal contacts are confirmed, the osteosynthesis screws are inserted according to the planning report sequence.

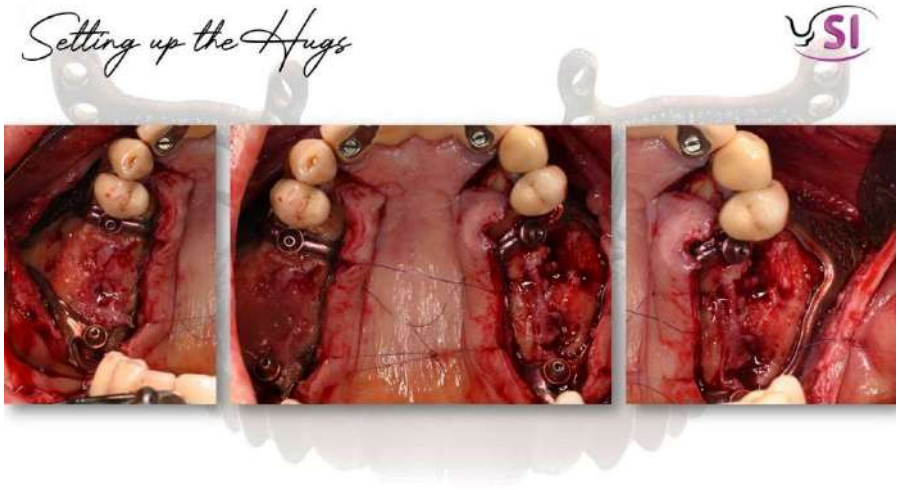


Figure 15.38 — Bilateral implant placement, bridge screwing in occlusion, and osteosynthesis screw fixation.

After bridge removal, bone grafting is performed over the entire bilateral implant surface. In this early case, collagen sponges (Collapat II) were used. Current protocol has evolved toward sticky bone covered by a resorbable membrane, which provides superior and more durable volume maintenance compared to resorbable collagen sponges alone.

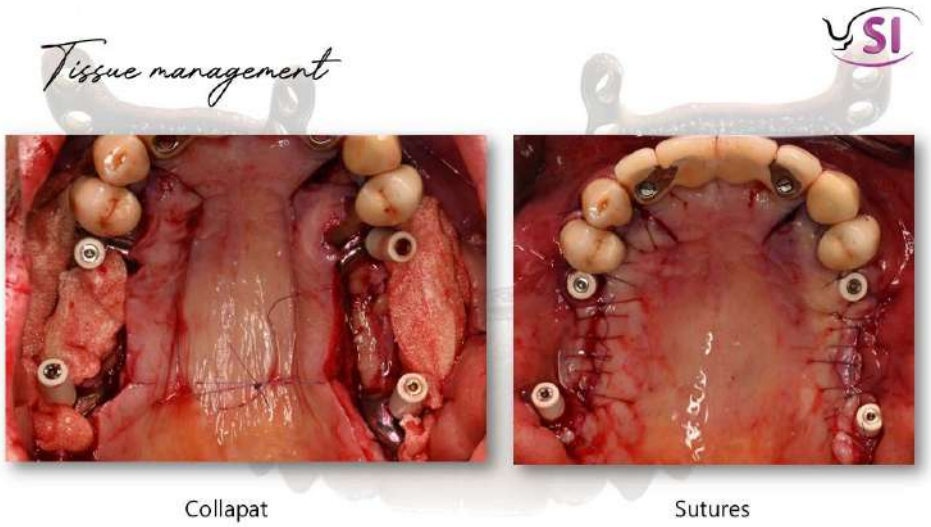


Figure 15.39 — Bone grafting, healing cap placement, and final suturing (right).

Healing caps are placed and the flaps are closed under zero tension. The temporary bridges are repositioned.

3.5 Postoperative Assessment

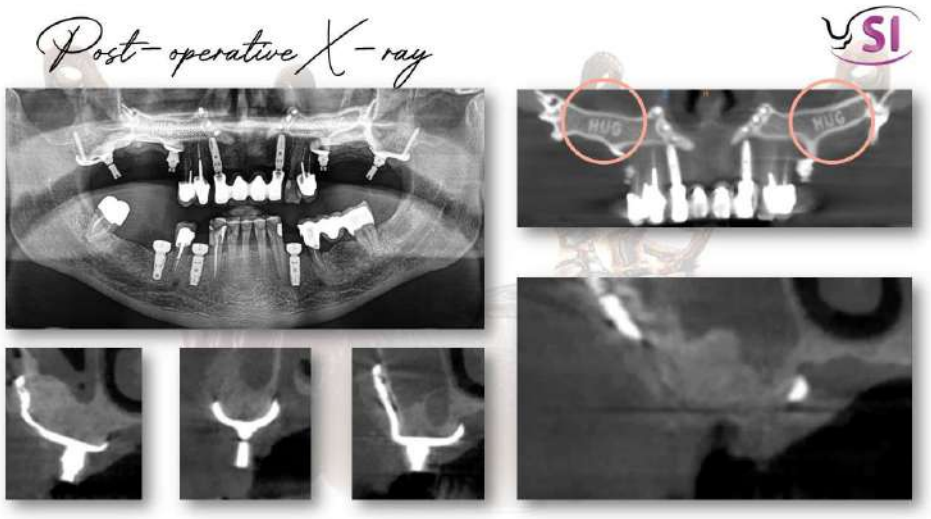


Figure 15.40 — Postoperative panoramic radiograph and CBCT sections. The implant traceability codes are visible in the lattice structure on the panoramic view.

Postoperative radiographic assessment confirms the excellent bilateral adaptation of both implant shells. The sinus cavities are completely avoided by the implant structures, consistent with the foundational principle of the graftless subperiosteal approach. The traceability codes embedded in the lattice structure are clearly identifiable on the panoramic radiograph, providing permanent identification of both components.

Case 4 — Full-Arch Mandibular Rehabilitation

Indication: Extremely Atrophied Fully Edentulous Mandible

> Full-arch mandibular rehabilitation in the context of extreme atrophy represents one of the most demanding surgical challenges in implant dentistry, even with the HUG® system. This case — a 75-year-old female— illustrates the complexity of managing a severely resorbed mandible with an irregular symphysis, thin bone above the inferior alveolar nerve, and an anatomy incompatible with conventional implant strategies. The solution: a three-part HUG® implant design combined with immediate definitive loading.

4.1 Clinical and Radiographic Assessment

Figure 15.41 — Complete mandible with extreme atrophy: severe symmetric bone resorption, highly irregular symphysis. The alveolar ridge morphology makes All-on-4 implant placement impossible.

The patient, a 75-year-old female, presented with an extremely atrophied fully edentulous mandible. The alveolar ridge, visible on both the intraoral photograph and the panoramic radiograph, is severely and symmetrically resorbed. The symphyseal area shows a highly irregular cortical surface. The proximity of the inferior alveolar nerve to the crest of the ridge makes standard endosseous implant placement — including tilted All-on-4 configurations — impossible. The subperiosteal approach is the only viable implant strategy for this anatomy.

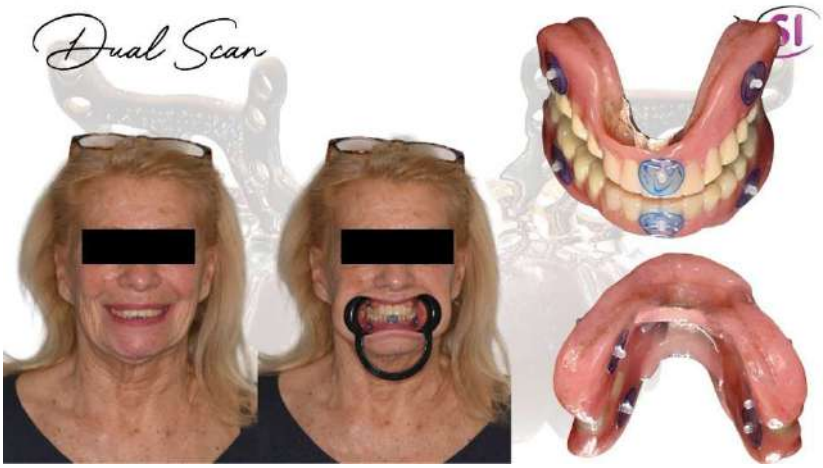


Figure 15.42 — Dual-scan protocol for mandibular full-arch case. Five radiopaque markers are bonded with cyanoacrylate to both the vestibular and lingual surfaces of the patient's existing complete mandibular denture. The denture has been relined with soft silicone to ensure stable intraoral positioning during the CBCT scan.

The dual-scan protocol is initiated identically to maxillary cases. Five radiopaque markers are distributed on both the vestibular and lingual surfaces of the existing mandibular denture to provide stable, non-redundant reference points for CBCT/STL alignment. The denture has been relined with soft silicone material to ensure reproducible seating in centric occlusion during the CBCT acquisition.

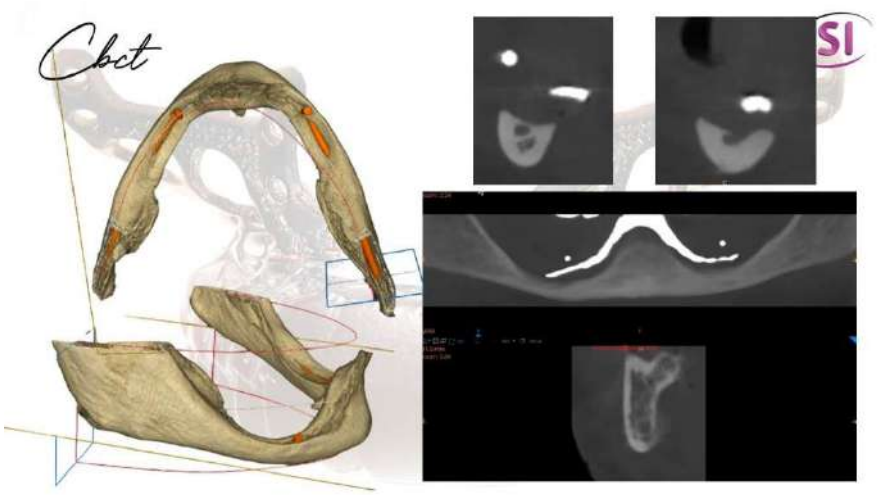


Figure 15.43 — CBCT 3D reconstruction and coronal sections.

CBCT analysis reveals the full extent of the bone atrophy. In the posterior regions, the bone height above the inferior alveolar nerve is critically limited. The mandibular symphysis is markedly irregular, with multiple prominences and depressions that must be addressed by bone reduction before implant placement.

4.2 Digital Design: Three-Part Implant Configuration

Given the severity of the atrophy and the irregular mandibular morphology, the implant was designed in three separate components: one anterior (symphyseal) shell and two posterior shells. This segmented design is necessary when the anatomy prevents the fabrication of 2 bilateral continuous shells — as is very commonly the case in severely resorbed mandibles.

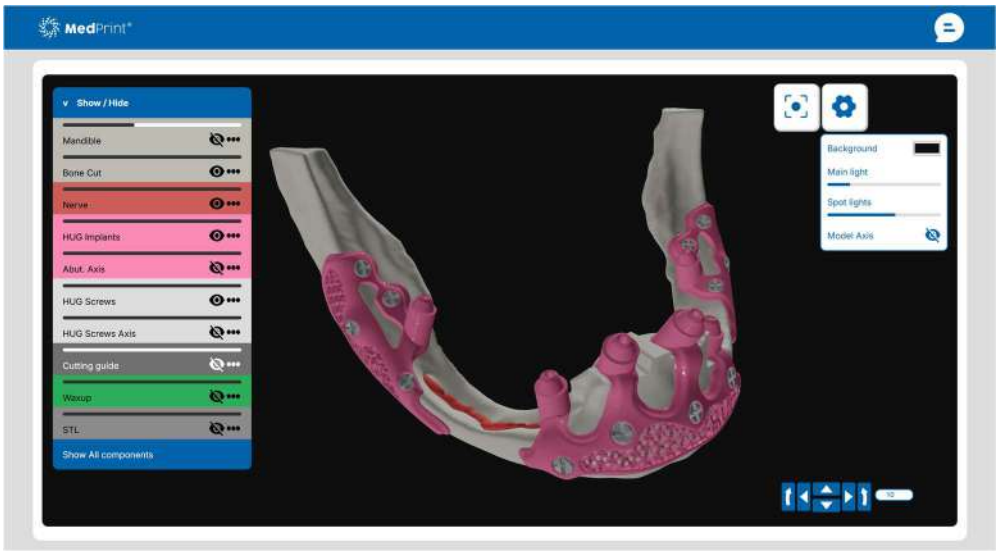


Figure 15.44 — MedPrint® design planning interface for the full-arch mandibular case.

The design process proceeds in the same sequence as all HUG® cases: bone reduction planning, bone cutting guide design, HUG® shell design, fixation screw positioning, and virtual validation. The extreme proximity of the inferior alveolar nerve to the bone surface in the posterior regions demands meticulous attention during both design and surgery.

Figure 15.45 — Three-part HUG® implant design (bottom row) and the resulting titanium SLS-printed components (top row).

The three titanium shells — anterior and two posteriors — are printed using selective laser sintering (SLS) in Grade 23 titanium (Ti-6Al-4V ELI). The gyroid lattice structure is incorporated into the bone-facing surfaces of all three components. A notable design adaptation in this case is the absence of a lingual band: the severity of the atrophy and the proximity of the inferior alveolar nerve make a lingual

extension impossible. In such cases, the implants rely exclusively on vestibular anchorage. The cohesion of the three-part system is provided by the definitive bridge, which rigidly connects all three shells through its screw-retained attachment to their respective abutments.

4.3 Surgical Procedure

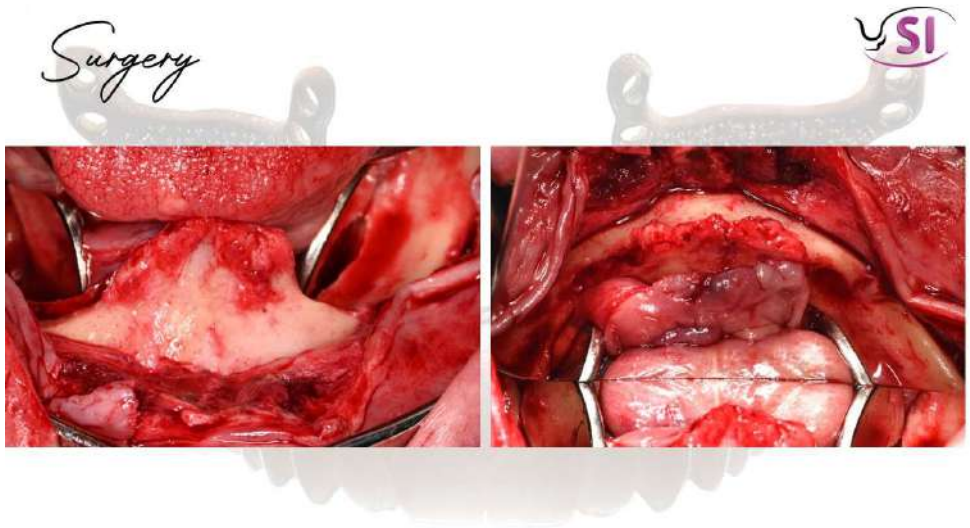


Figure 15.46 — Anterior ridge after full-thickness flap elevation. The irregular, knife-edge crest of the mandibular symphysis is clearly apparent. Bone reduction is mandatory before implant placement to create a flat, stable surface.

The incision is made along the thin band of attached crestal gingiva. A median sagittal incision facilitates symmetric flap elevation. Full-thickness flaps are raised both vestibularly and lingually. The mental foramina are identified bilaterally and protected throughout. The mylohyoid muscle attachments are released on the lingual side. The mentalis muscle fibres are carefully detached from their anterior mandibular insertions. Temporary stay sutures are placed on all flap components to stabilise the surgical field.

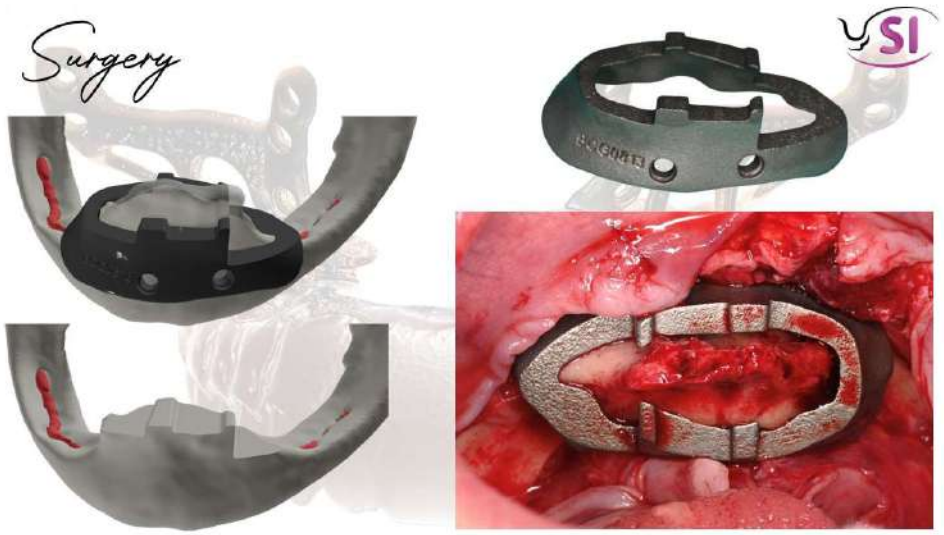


Figure 15.47 — Bone cutting guide positioned on the anterior mandible.

The bone cutting guide is positioned and fixed with two small cortical osteosynthesis screws. Bone reduction is performed with a Lindemann bur mounted on a handpiece under copious saline irrigation. This step is critical: the amount and topography of bone removed must match exactly what was planned virtually, to allow the implant to seat passively. After guide removal, all edges are rounded and polished.

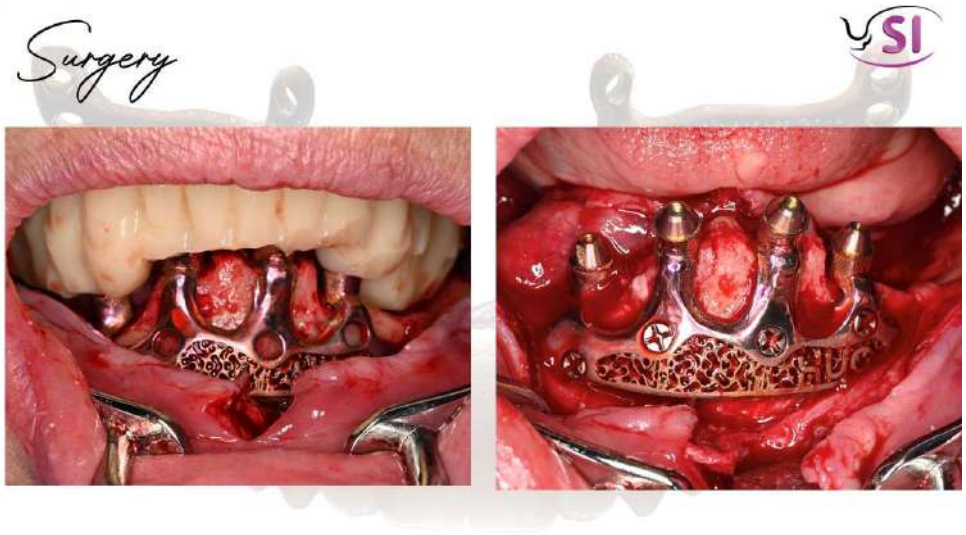


Figure 15.48 — After bone reduction: placement of all three HUG® shells, trial of the definitive bridge, and occlusal verification. The bridge is kept in centric occlusion while the osteosynthesis screws are inserted.

The three implant components are positioned sequentially: anterior shell first, then right and left posterior shells. The definitive bridge is then screwed onto the abutments, and the patient is asked to occlude in centric relation. The bridge stabilises the three shells in their correct mutual positions while osteosynthesis screws are inserted. This simultaneous loading strategy is a fundamental feature of the HUG® concept: the bridge acts as a passive rigid connector that links the three components and transmits occlusal forces coherently to the bone.

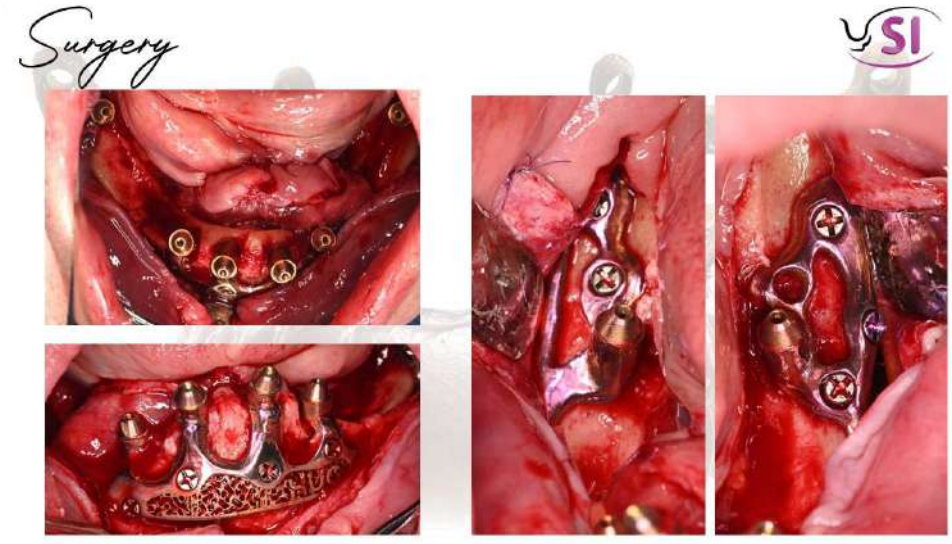


Figure 15.49 — After bridge removal: occlusal and vestibular views of the anterior and posterior implant shells with their fixation screws.

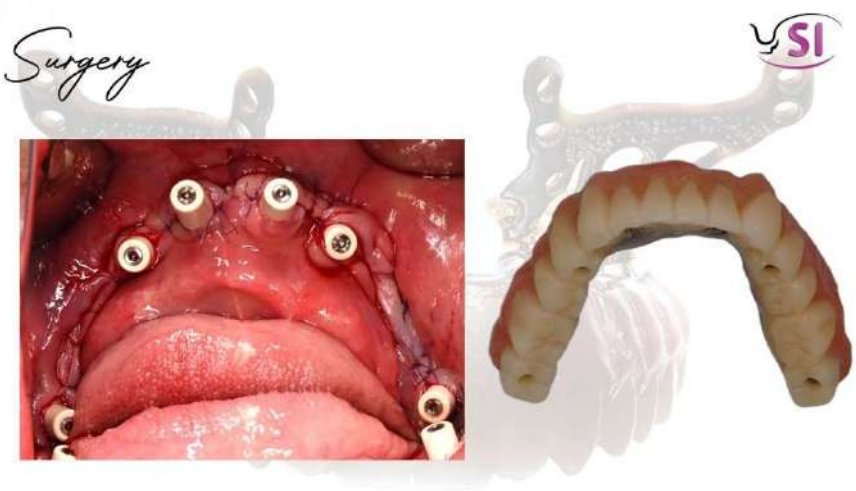


Figure 15.50 — Healing caps placement, bone grafting over the entire implant surface, PRF membrane coverage, and final suturing. The bridge is definitively repositioned at the end of the procedure.

After confirming the rigid fixation of all three shells, the bridge is removed and bone grafting is performed over the entire implant surface, including where possible on the lingual aspect. PRF membranes cover the grafted area.

Healing caps are placed, and the flaps are sutured under zero tension, using periosteal releasing incisions where necessary. The definitive bridge is repositioned and the procedure is concluded. As in all full-arch HUG® maxillary cases, the patient is immediately discharged with a complete fixed mandibular restoration.

4.4 Postoperative Assessment and Follow-Up

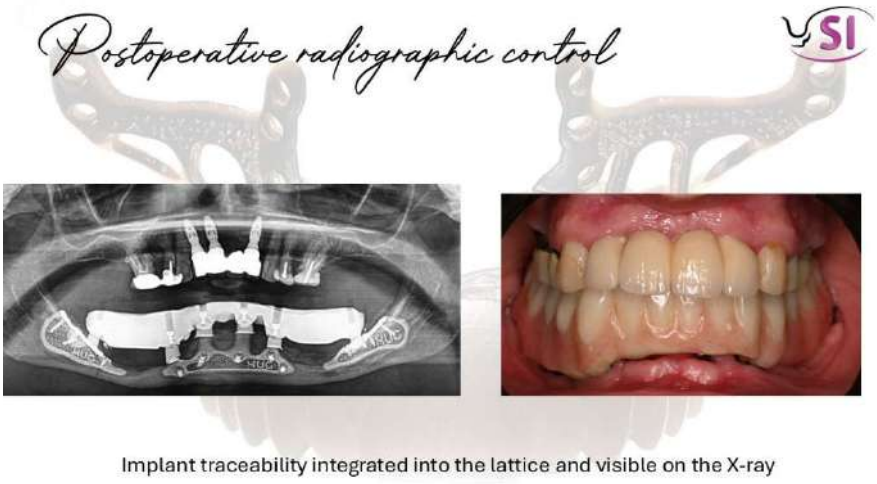


Figure 15.51 — Postoperative panoramic radiograph and CBCT sections.

The postoperative radiographic assessment demonstrates excellent adaptation of all three implant shells to the mandibular bone surface. A notable feature of the HUG® system is the integration of a traceability code into the lattice structure, which is visible on standard radiographs and allows implant identification at any future follow-up, regardless of the interval elapsed.

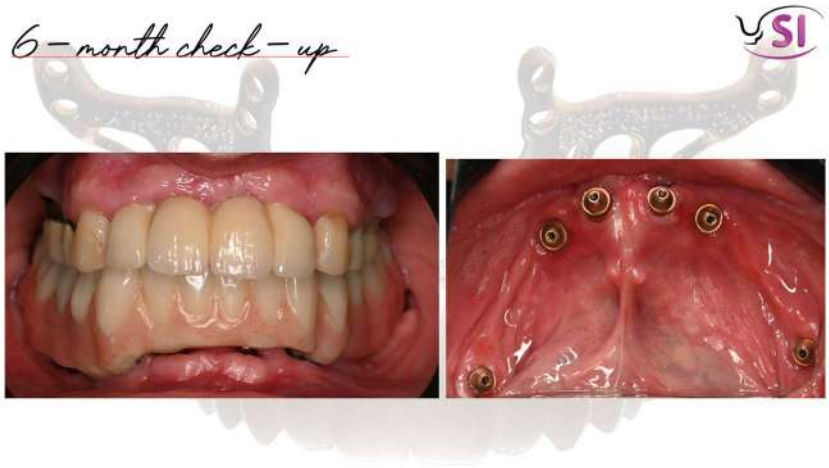


Figure 15.52 — Six-month clinical follow-up showing excellent soft tissue integration around the implant.

Three-dimensional CBCT analysis at each implant component independently confirms the safety of the nerve relationship: the inferior alveolar canal is not contacted by any part of the implant structure. At six months, the clinical photograph reveals a slight retraction of the soft tissue under the bridge — a phenomenon that is not only acceptable but actively desired: it creates a hygienic space under the bridge, facilitating interdental cleaning and allowing the patient to maintain optimal oral hygiene. The bridge-on-stilts configuration is the target functional outcome in full-arch mandibular cases.

Clinical Case conclusions

> Subperiosteal implants are not magic. They require a method, a concept, and a proven workflow. These four cases demonstrate that the HUG® system, when correctly indicated and executed, offers a genuinely transformative therapeutic option for patients who have historically been denied fixed implant rehabilitation due to extreme bone atrophy.

The four clinical cases presented in this chapter cover the full spectrum of HUG® indications: the fully edentulous atrophic maxilla, the partially edentulous mandible with limited bone above the inferior alveolar nerve, the fully edentulous atrophic mandible, and the posterior maxilla complicated by sinus pathology and oroantral communications. Together, they demonstrate several principles that are common to all HUG® treatments.

First, **prosthetic primacy**: the design workflow begins and ends with the prosthetic project. The implant is designed to serve the prosthesis, not the reverse. This prosthetically driven approach ensures optimal functional and aesthetic outcomes regardless of the underlying bone morphology.

Second, **digital precision**: the combination of CBCT, intraoral scanning, dual-scan alignment, virtual design, and 3D printing in Grade 23 titanium produces a custom device with an anatomical fit that is impossible to achieve by conventional means. The passive seating of the implant on the bone surface — confirmed intraoperatively in every case — is a direct result of this precision.

Third, **biological integration**: the HUG® implant is not purely subperiosteal. The gyroid TPMS lattice structure, combined with bone substitutes and collagen membranes, promote guided bone regeneration over the implant surface, progressively converting the device into a partially intraosseous structure. In the posterior mandible, a two-stage surgical approach is an essential component of achieving successful biological integration. Radiographic evidence of this bone regeneration can be observed from the fourth month onwards and represents one of the most important conceptual advances in the modern understanding of subperiosteal implants.

Fourth, **clinical efficiency**: full-arch cases are completed in a single surgical session, from edentulous atrophic anatomy to a definitive fixed bridge. Partial cases require a second surgical stage at four months for implant uncovering, but the total treatment duration remains significantly shorter than any bone regeneration alternative. For elderly or medically compromised patients, the reduction in surgical burden is not merely convenient — it is clinically meaningful. The benefit–risk ratio of this solution is truly excellent, as is the feedback from patients.

The HUG® concept continues to evolve. Protocols are refined with each generation of cases, and the indications are progressively expanding. As the scientific evidence base consolidates and the learning curve is better characterised, subperiosteal implants are positioned to become a standard-of-care option for patients who would otherwise have no access to fixed implant rehabilitation.

Epilogue

Towards the Future of Subperiosteal Implantology

The HUG® Concept is not a finished product. It is a living clinical framework — one that continues to evolve with every case placed, every piece of feedback received, and every research study completed. What we know with confidence today is more than enough to deliver reliable clinical results. What we will know tomorrow will make those results even more predictable.

What We Have Established

Across nine pillars and two volumes of this book, we have attempted to present the complete scientific and clinical rationale behind every decision embedded in the HUG® Concept. The message is not that the HUG® system is perfect — no medical device or protocol is. The message is that every decision has been made for a reason, and those reasons are documented, peer-reviewed, and open to scrutiny.

The biological foundation is solid: Ti Grade 23 ELI can osseointegrate, the gyroid lattice supports it, and biomaterial coverage of the implant body makes it consistent. The mechanical validation is rigorous: every implant is individually evaluated by finite element analysis, and the 1.5 mm arm thickness recommendation is based on quantified safety margins.

The prosthetic design prioritizes hygiene and tissue health over aesthetic idealism. The digital workflow provides traceability, transparency, and a level of pre-operative validation previously unavailable in subperiosteal implantology.

The Honest Assessment

We are at a turning point — not at the destination. Long-term data on the HUG® Concept are not yet available. The optimal biomaterial combination for bone formation above the implant is still being refined. Dermal matrix is showing promising results in mandibular cases, but follow-up remains limited.

These are not reasons to delay treatment, but rather reasons to proceed carefully, adhere strictly to the protocol, and contribute clinical data to the growing body of evidence. To support this objective, we have established an online community (Circle) bringing together HUG users and trainees of the Subperiosteal Institute. This platform provides clinical support, facilitates the exchange of experience, and allows continuous feedback on the evolution of the concept. The collaboration between clinicians, the feedback loop with Biotech Dental, and the academic activities of the Subperiosteal Institute all contribute to the continuous improvement and validation of this treatment approach. If you wish to join this community, we would be pleased to welcome you.

The Final Message

First, forget everything you know about conventional implant dentistry. Do not attempt to transpose the prosthetic concepts, surgical principles, or treatment protocols developed for endosseous implants to subperiosteal implants. This is a fundamentally different form of implant therapy. The indications, biomechanical principles, soft tissue management, and even prosthetic reconstruction, must all be reconsidered. Concepts, protocols, and clinical guidelines need to be rewritten specifically for this new generation of digital subperiosteal implants.

If there is one conclusion to draw from this book, it is this: a subperiosteal implant placed without a conceptual framework may lead to a high rate of soft tissue complications, with recession rates approaching 30% in some published series. However, these implants may continue to function successfully despite the presence of soft tissue recession, as recession itself is not necessarily synonymous with implant failure.

Conversely, a subperiosteal implant placed with strict adherence to the nine pillars of the HUG® Concept should produce more predictable outcomes, reduce biological complications, and improve long-term tissue stability.

The framework is the difference. Not the implant alone—the concept.

— Dr Antoine Diss · Dr Laurine Birault

Subperiosteal Institute, Nice, France